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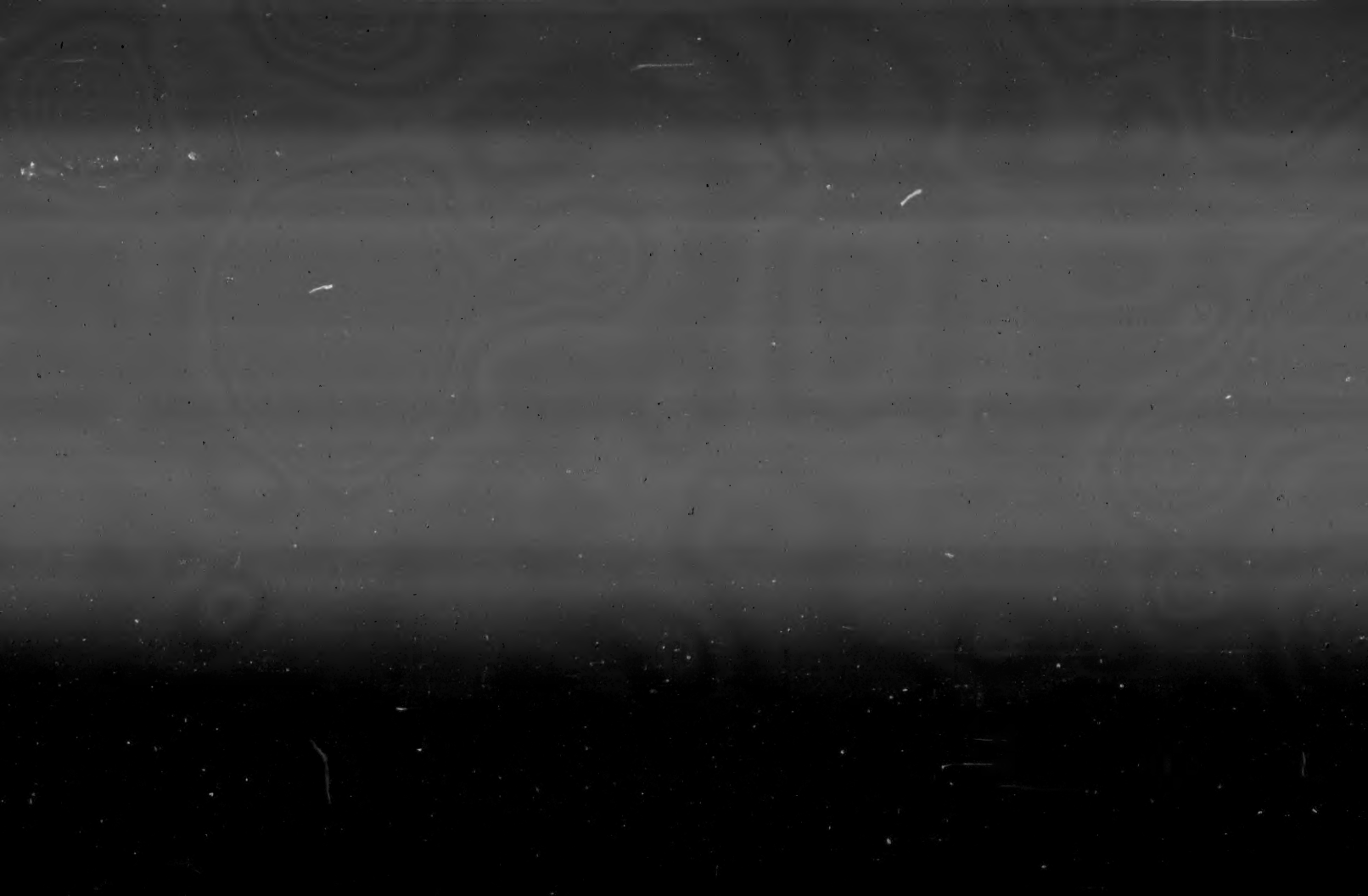

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[THIRD SERIES.]

ART. LV.—*On Endothermic Decompositions obtained by Pressure. Second Part. Transformations of Energy by Shearing Stress;* by M. CAREY LEA.

OF the relations which exist between two forms of energy, mechanical and chemical, very little if anything is known. In the second volume of his Lehrbuch, Ostwald remarks that as to these relations "almost nothing" is known.*

There are certain familiar cases in which mechanical energy may seem at first sight to be converted into chemical energy. The fulminates, iodimide, and other substances explode by shock. But it is hardly necessary to remark that all such reactions are exothermic and need an external impulse only, to start them—if this impulse were not needed such compounds could not exist at all. Were such reactions taken as true transformations of energy an absence of due relation between cause and effect would be involved. For the shock that suffices to explode a grain of fulminate will equally explode a ton. The faint spark that will explode a grain of gunpowder will also explode a magazine.

Present opinion holds undoubtedly that no true transformation of mechanical into chemical energy is known. Most text books do not consider the question at all. But Dr. Horstmann in the volume of theoretical chemistry which forms part of the last German edition of Graham Otto's Chemistry, discusses the

* "Andererseits ist von der Verhältnis zwischen mechanischer und chemischer Energie, fast nichts bekannt." A few lines below, this remark is repeated with emphasis. Lehrbuch, 2d German ed., vol. ii, p. 12.

matter. His views are so much to the point that I shall translate a few sentences, putting in italics the statements to which I would specially refer.

"We must consequently admit that through a rough mechanical attack the molecular structure of certain chemical compounds can be disrupted and destroyed. This will certainly be possible only for compounds in whose molecules the arrangement of the atoms does not correspond to a stable equilibrium and in which therefore the chemical energies themselves are already striving to form simpler and more stable compounds out of the constituents of the existing substance. *For it cannot be admitted that actual chemical changes can be brought about by a mechanical impulse.*" (l. c., p. 350).

In another chapter he says with equal distinctness:

"*By mechanical means alone no reaction against the force of chemical energy can be brought about.* By a shock or blow the molecular structure of chemical compounds can indeed be so far loosened that free play is given to chemical forces; *but against these forces we cannot by mechanical means separate the atoms nor combine them in a definite way.*" (p. 594).

These expressions of a distinguished chemist will sufficiently indicate what has been up to the present time the opinion of chemists as to the possibility of transforming mechanical energy into chemical.

In the first part of this paper I believe I have been able to show in a qualitative way the production of true endothermic reactions by mechanical force. In the present part I hope to show an increased number of such reactions and in one case to exhibit actual quantitative results, at least so far as to obtain the product of the transformation in weighable quantities.

In the first part decompositions were described that were brought about by *simple pressure*. Compounds formed by exothermic reactions, and therefore requiring expenditure of energy to break them up, were decomposed. The investigation might probably have been made to include a still larger range of substances. But it was found that the efficiency of pressure was so enormously increased by the addition of shearing motion, that decompositions requiring a force of hundreds of thousands of pounds with pressure alone, could be effected by the mere strength of the hand when shearing stress was used. More than this, decompositions which enormous pressures failed to effect, readily took place under the action of shearing stress.*

* It would not have been difficult to obtain much greater pressures than those described in the first part of this paper. This could be effected by means of the differential screw. I had planned for a screw with threads of 40 turns in 10 inches

(I)

It was mentioned in a previous paper on the decomposition of the silver haloids by mechanical force that when silver chloride was sharply ground for some time in a mortar, both the pestle and mortar became covered with a deep purple varnish of silver photochloride, thus indicating a partial reduction to subchloride. It has since proved that there is no more effectual method than this of applying shearing stress and that in this way a number of quite stable chemical compounds formed by exothermic reactions can be broken up. The mortar and pestle should be very solid and of unglazed porcelain. With metal, there would be danger of action between the metal and the substance and with agate mortars sufficient force cannot well be applied. In many cases success depends on the exertion of great pressure on the pestle. It is also absolutely essential that the quantity of material acted upon should be small. When a larger quantity is employed the particles slip or roll over each other and thus escape the action of the stress. It is no doubt for this reason that the very remarkable results which can be obtained in this way have hitherto escaped attention.

A small quantity, a few decigrams, of the substance having been placed in the mortar the first thing is to spread it in a thin uniform coat over the bottom and part of the sides. The pestle is then to be rotated with the utmost force that can be exerted.

Sodium Chloraurate.—The salts of gold are particularly well adapted to this examination as the reduction is complete

and 39½ turns in 10 inches respectively. The mechanical efficiency of such a screw is that of one having 320 turns to the inch if such a thing were practicable, at the same time that a thoroughly strong construction can be obtained. The massive steel nut to advance ⅛ of an inch would require 40 full turns of this screw.

This arrangement compares as follows with that previously employed. In it to cause the vise jaws to approach by 1 inch required that the point of the lever at which the force was applied should pass through a space of 113·1 feet: this relation, 1 inch to 113·1 feet or 1 : 1357·2 gives the measure of the efficiency of the instrument.

With the double screw, on the other hand, to cause the nut to advance ⅛ of an inch the end of the lever (2 feet long) must pass through a space of 500 feet or in the proportion of 1 inch to over ⅘ of a mile. The circumference described by the lever being approximately 12½ feet and the screw requiring 40 turns to advance the nut ⅛ of an inch we get the proportion of 1 inch to 4,000 feet, or 1 to 48,000, which is the measure of the efficiency of such an instrument. Therefore, supposing two men to pull on the end of the lever each with a pull of 100 lbs. the pressure exerted on the nut (disregarding loss by friction) would be 9,600,000 lbs., which could be doubled by using a 4-foot lever.

Such a combination is quite practicable, the only real difficulty being to obtain sufficient solidity of construction to resist the strain. I had made drawings for this instrument, but gave it up in consequence of observing the enormously greater efficiency of shearing stress as a means of transforming mechanical into chemical energy.

and the gold appears in the metallic state so that it can be weighed and the exact amount of reduction can be fixed. It will be seen by (3) below that it may amount to as much as over 4 per cent of the gold present.

(1) Two or three decigrams of chloraurate with a moderate trituration left 1·8 milligram of metallic gold. Under the action of the pestle the yellow color of the salt gradually deepened to an olive shade. When water was poured on, the undecomposed salt dissolved, leaving the gold as a delicate purple powder. The color of the gold being purple instead of the more usual brown shade explains the olive color just mentioned, yellow and purple combining to form olive.

(2) Half a gram of the salt was taken. This specimen was more neutral than the preceding and was therefore more easily reduced. Half an hour's trituration had for effect the reduction of 9·2 mgs. of gold.

(3) A similar treatment of the same quantity of chloraurate resulted in the separation of 10·5 mgs. of gold.

These may seem at first somewhat small proportions. But it is to be recollected that the force is necessarily applied at a disadvantage and that the equivalent in work of chemical affinity is always very large. In the present case the figures are as follows: Thomsen found as the heat equivalent for the combination of gold with chlorine to form auric chloride 28·8 great calories. Taking the atomic weight of gold as 197, we find that one gram of gold in forming auric chloride disengages 115·7 small calories or water-gram-degrees, whose equivalent, taking Rowland's determination, is 49,288·2 gram-meters corresponding to $4{\cdot}83 \times 10^9$ ergs or 483 joules.

The small quantity of gold reduced in (3), 10½ milligrams, would by conversion to auric chloride generate 1·215 water-gram-degrees of heat whose equivalent in work is 518 gram-meters. As heat is a degraded form of energy such an actual transformation without loss to a higher form would be impossible. It is more correct to say, therefore, that the amount of energy which would raise 518 grams to the height of one meter can be transformed into the same amount of heat, 1·215 water-gram-degrees, as is evolved by 10·5 mgs. of gold by conversion into auric chloride. Consequently this work, 518 gram-meters represents the amount of mechanical energy transformed into chemical energy in operation [3].*

It does not appear that in effecting these reactions and the others which remain to be described, mechanical energy under-

* The amount of energy required would in fact slightly exceed this as the thermochemical equivalent of formation of sodium chloraurate would slightly exceed that of auric chloride. For the chloraurate I do not find a determination, but preferred to use this salt in the operation as being both more stable and more neutral, than auric chloride.

goes an intermediate conversion into heat. Rapid movements are not needed, what is required is strong pressure with movement, but this need not be rapid. Nor does the mortar or the pestle become sensibly warm. The operation does not need to be continuous but may be broken up with any number of intervals. But a decisive conclusion can be drawn from those cases in which decompositions are effected in this way that *cannot be produced by heat.* For example, in the next instance to be mentioned there is a partial reduction of corrosive sublimate to calomel. By heat, corrosive sublimate sublimes unaltered and the same is true of mercurous chloride. The three silver haloids fuse unchanged at a red heat. The same conclusion can be drawn from other reactions.

These results were obtained in an atmosphere absolutely free from dust so that the reducing action of this substance was completely excluded.

Mercuric Chloride.—A specimen which after lightly powdering did not darken in the least with ammonia, was triturated in the manner just described with several intervals, in all for 15 minutes. It then became gray in a very striking way when moistened with ammonia.

This is a very interesting reaction. In the first part of this paper it was mentioned that mercuric chloride could be subjected to a pressure of about 70,000 atmospheres absolutely without change. It appears, however, that a pressure amounting to less than a hundred pounds causes decomposition when combined with movement, showing the enormously greater efficiency of shearing stress as compared with simple pressure. Not only this but as just mentioned shearing stress produces decompositions which heat is not competent to effect.

Mercurous Chloride.—When calomel was sharply triturated in a mortar it first became yellow and then blackened without difficulty.

Turpeth Mineral, $3HgO, SO_3$.—Reduces rather slowly.

Mercuric Oxychloride, $2HgO, HgCl_2$, obtained by precipitating corrosive sublimate by potash acid carbonate, exhibited the following reaction. Its brownish purple color by light grinding became lighter and then when strong force was used it blackened with remarkable ease.

Mercuric Iodide shows a trace of blackening.

Mercuric Oxide.—This substance yields much more readily to trituration than to simple pressure. Especially on the sides of the mortar it was quite blackened. The layer of material must be quite thin otherwise little effect is produced.

Platinic Chloride.—Gradually darkened in a very marked way, finally becoming blackish.

Ammonium Platinichloride gave same result.

Silver Tartrate.—When spread in a very thin skin over the mortar each sharp stroke of the pestle left a black line behind it. This is a strong constrast with the complete resistance of this substance to simple pressure.

Silver Carbonate.—Action similar.

Silver Citrate.—Blackens very easily.

Silver Oxalate.—At least as easily.

Silver Arsenate.—Nearly as easily.

Silver Sulphite.—Effect visible in five minutes and gradually increasing. Very well marked.

Silver Salicylate.—No silver salt appears to be so easily reducible as this. Every sharp stroke of the pestle leaves a brown mark behind it.

Silver Orthophosphate.—Affected easily. After the phosphate has been a good deal reduced the unchanged part may be dissolved out with ammonia. The black residue after washing readily dissolves in dilute nitric acid and the solution gives a white cloud with hydrochloric acid.

Potassium Ferridcyanide.—A crystal of the pure salt sharply ground in a mortar becomes in portions brown and in others blue. The quantity used must, as indeed in all of the above cases, be small, one or two decigrams. If a little distilled water be added an insoluble blue powder is left behind and the solution formed strikes a blue color when added to one of ferric alum. This indicates that the decomposition is twofold. The experiment is quite a striking one and the result is easily obtained.

(II)

This form of mechanical force, shearing stress, may be applied to effect endothermic change in other ways. A very simple, and at the same time very efficient, method is that of pressure with a glass rod. Pure strong paper is to be imbued with a solution of the substance, if it is soluble, or if not, it is to be made into a paste with water and then applied with a brush. The paper is to be then very thoroughly dried and is to be laid upon a piece of plate glass. Characters are to be marked on it with the end of a glass rod that has been rounded by heat, using as much pressure as is possible without tearing the paper.

More than twenty years ago I was able to show that marks made in this way on sensitive photographic films could be developed, as an invisible image had been impressed. That, however, is a somewhat different matter from actual and visible decomposition following each stroke of the rod, a result which may be obtained with various salts of gold, mercury, silver and other metals.

Potassium Ferridcyanide.—Pure paper was imbued with a dilute solution of this salt. After thorough drying it was laid on a glass plate and marks were made with a glass rod in the manner just described. These marks were immediately visible and when the paper was plunged into dilute solution of ferric ammonia alum or of ferric chloride they became dark blue. It is probable that the decomposition here effected was twofold (see above).—The *nitroprussides* appear to be much more stable than the ferridcyanides. When sodium nitro prusside paper was treated with pressure, followed by appropriate reagents, no indications of decomposition were obtained.

Auric Chloride.—Paper imbued with a solution of auric chloride and marked in the manner described was thoroughly soaked in water to remove, as far as possible, the rest of the gold salt. The marks were very distinct and gradually gained with time. Color dark purplish gray.

Platinic Chloride.—After drying and marking, the paper was thoroughly soaked in water and dried. The marks were very distinct, of a yellow color.

Ammonium Platinichloride.—Marks very visible. Continued to slowly deepen, and in a few weeks were almost black.

Silver Carbonate.—The traces of the rod were brown. When the paper was placed in ammonia the carbonate dissolved, but the marks resisted the action of the ammonia and remained.

Silver Phosphate.—Action very similar to the preceding.

Silver Arsenate.—Similar action.

Silver Tartrate and Oxalate.—These salts gave analogous results to the preceding, but not so well marked. The carbonate phosphate and arsenate show this reaction best and about equally well. What is rather curious is that silver chloride does not exhibit a visible action.

Mercuric Oxide.—Paper imbued with a saturated solution of mercuric nitrate and then treated with solution of potash and dried shows this reaction very distinctly. Mercuric oxide appears to be quite sensitive to light.

Turpeth Mineral.—Mercuric sulphate was dissolved in water with the aid of sulphuric acid. Paper was soaked in the solution, allowed to become nearly dry and then washed. This paper showed the reaction very moderately, but the marks were brought out more strongly by immersion in ammonia.

Ferric Alum (ammonia).—Paper imbued with solution of this salt dried and marked was immersed in solution of potassium ferridcyanide. The marks came out blue showing that the ferric salt had undergone partial reduction.

It is easily conceivable that the action of shearing stress should be enormously greater than that of simple pressure. For it seems probable that pressure can only cause decomposition when the resulting product is more dense, has a greater specific mass, than the original substance. With shearing stress the case is altogether different. All matter is in a state of vibration and it is easily conceivable that the forcible friction of a hard substance may increase vibration in somewhat the same way as does a bow drawn over a stretched cord. Both the elasticity and the tension of the atoms themselves are vastly greater than those of any stretched cord so that the increased vibration may easily be sufficient to shatter the molecule.

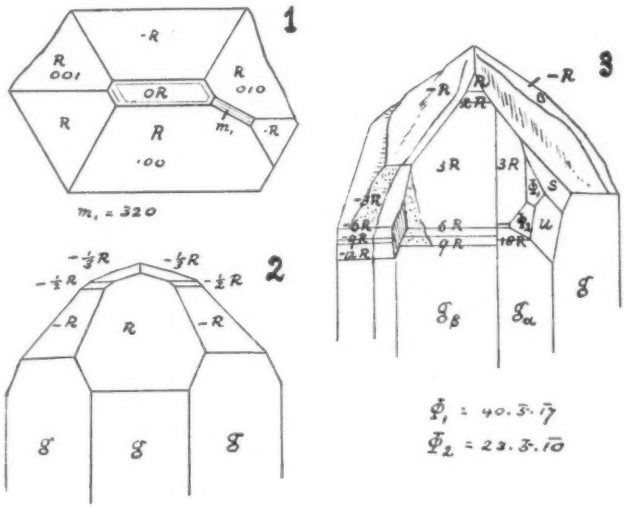
The transformation of light, heat, and electricity into mechanical energy as well as the converse transformations are extremely familiar. That mechanical energy may be transformed into chemical energy is proved by the results in these papers described. The converse transformation, that of chemism into work, is in an industrial point of view by far the greatest chemical problem now waiting for solution. But it is by no means certain that such a transformation is practically possible. At least it seems probable that the improvement in our method of obtaining work from the chemism of carbon may be in the direction of substituting electricity for heat as the intermediary.

Art. LVI.—*Quartz from the Emerald and Hiddenite Mine, North Carolina;* by H. A. Miers

The remarkable crystals of quartz from this locality have been the subject of several memoirs by the late Professor G. vom Rath, which render it unnecessary to say anything regarding the general features of the North Carolina quartz. The following note, which relates to three interesting crystals recently presented to the British Museum by Mr. W. E. Hidden, serves to confirm and supplement the observations of vom Rath, concerning the rare planes which occur upon some of the more highly modified crystals from the Hiddenite mine. In the accompanying diagrams the crystals are drawn and lettered in accordance with the position and notation adopted by vom Rath in order to facilitate reference to his figures.

Crystal No. 1 is remarkable as showing a very well developed basal plane (fig. 1); the crystal is a pyramid R, $-R$, broken at its lower end so that no prism faces are visible; the

apex is truncated by a smooth face which is certainly as perfect an example of the basal plane upon quartz as any which exist. The face is dull and slightly rounded, and the central portion is slightly raised above the edges as indicated in the figure, but it is sufficiently smooth to yield an image on the



reflecting goniometer. Measurement in the zone $R:-R$ = [100 : $\bar{1}$22] gave a series of images occupying an angular breadth of about 3½°:

R:	$0R$ =	49° 24′	to	52° 51′	mean	51° 7½′
$-R$:	$0R$	50 44	to	54 11	"	52 27½′
$R:-R$		103 34¾				
R:	$0R$	51 47	calculated.			

This face has all the appearance of a corrosion surface and I share the opinion of Molengraaf that most of the rare planes upon the North Carolina quartz have been produced in this way.

The crystal is further remarkable for one of the very rare planes which replace the edges of the primary rhombohedron; only one such edge is developed in the present instance and it is replaced by a face m which is rounded in the zone RR.

This surface yields a series of somewhat indistinct images in the zone RR which correspond to the following inclinations to (100).

$hk0 : 100$	$\frac{h+k}{h-k}$
31° 34′	4·64
31 59	4·82
32 26	5·03
32 54	5·28
34 3	5·98
34 47	6·52

The first four images are the best; the angle RR was measured as 85° 45¾′.

This face or corrosion surface is doubtless identical with that described by vom Rath* from the same locality as a right hemi-scalenohedron replacing the edge RR, and accompanied by $-\frac{1}{2}R = \{110\}$, the symbol being $-\frac{11}{18}P\frac{11}{7} = \{11.7.0\} = \{4.7.\bar{1}1.18\}$.

The above measurements show that the face may with greater probability be referred to the form $\{320\} = -\frac{3}{5}P\frac{3}{2} = \{12\bar{3}5\}$ for which the angle is $100 : 320 = 32° 23\frac{1}{2}′$, $\left(\frac{h+k}{h-k} = 5\right)$. The angle measured by vom Rath was 31° 13′ (approximate). The order of the rhombohedral axes adopted here is such as to harmonize with the indices of previous authors who have used the Millerian system in describing new faces on quartz.

Crystal No. 2 exhibits a very unusual habit (fig. 2), being terminated by three large and well-developed faces of the obtuse rhombohedron $-\frac{1}{3}R = \{441\}$ which gives it the aspect of a calcite termination. This extremely rare face was observed by vom Rath on a curious crystal from the same locality (Zeitschr. f. Krystallographie, x, 170, Taf. vi, fig. 5). There, as in the present instance, the form $-\frac{1}{3}R$ is accompanied by small planes of $-\frac{1}{2}R$ which truncate the edges of the primary rhombohedron; but the measurements of vom Rath were insufficient to establish the symbols with certainty.

On the crystal represented in fig. 2 the faces of $-\frac{1}{3}R$ are dull and drusy as though due to a corrosion which has also spread partly over the small faces of $-\frac{1}{2}R$; the latter are otherwise smooth and reflect well; the inclinations of $-\frac{1}{3}R$ can be measured with perfect accuracy after the faces have been slightly oiled.

	Measured.	Calculated.
$-R : -\frac{1}{2}R$ =	19° 21′	19° 22′
$-R : -\frac{1}{3}R$	28 48	28 50

Crystal No. 3.—This crystal, represented in fig. 3, is interesting on account of two faces Φ_1 Φ_2 which are right positive hemiscalenohedra lying out of the usual zone Rsu.

* Zeitschr. f. Krystallographie, x, 172.

The crystal is somewhat difficult of measurement on account of the uneven nature of the principal rhombohedron faces, and the usual horizontal striæ and vertical reëntrant angles upon the prism.

The faces $-R$ of the figure are curved and only retain a small plane surface near their right-hand edges which yields a brilliant reflection belonging to $-R$. The prism faces g_β g_a make a reëntrant angle of 0° 20½′ but g_a is inclined at 59° 59′ to g.

The indices of Φ_1 and Φ_2 can therefore be best fixed by measuring the inclinations of these faces to g_a g_β s and u; care being taken to employ the right hand portion of $3R$, since this face has a vertical reëntrant angle (indicated in the figure) of 0° 16′.

The form Φ_1 has been observed by vom Rath on similar crystals from this locality (Zeitschr. f. Krystallographie, xii, 453, Taf. viii, fig. 1) and has the symbol

$$40.\bar{5}.\bar{1}7 = \tfrac{1}{6}^{9}P\tfrac{1}{15}^{9} = 15.4.\bar{1}\bar{9}.6$$

established without any doubt by the following measurements:

	Measured.	vom Rath.	Calculated.
$3R : \Phi_1 =$	11° 9′	10° 57′—10° 50′	11° 8¼′
$s : \Phi_1$	19 33	19 54 —19 56	19 38¾
$u : \Phi_1$	3 51	3° 57	3 43
$g_a : \Phi_1$	19 12		19 1
$g : \Phi_1$	50 16		50 14

The face Φ_2 presents somewhat greater difficulty; it yielded the following measurements:

		Calculated for	
	Measured.	$\Phi_2 = 23.\bar{5}.\bar{1}0$	$\Phi_2 = 32.\bar{7}.\bar{1}\bar{4}$
$3R : \Phi_2 =$	8° 26′	8° 30¼′	8° 34¼′
$s : \Phi_2$	24 25½	24 27	24 30¼
$u : \Phi_2$	5 57	5 44¼	5 43¼
$g_a : \Phi_2$	14 4	14 4¼	13 58
$g : \Phi_2$	52 18	52 49½	52 46

The measurements suggest as the simplest symbol:

$$\Phi_2 = 23.\bar{5}.\bar{1}0 = \tfrac{3}{8}^{3}P\tfrac{3}{2}^{3} = 28.\bar{5}.\bar{3}\bar{3}.8$$

With indices of such complexity, however, which seem to be scarcely subject to the law of rationality it is important to ascertain whether a slight change of the numbers will not bring the position of the face into harmony with others of the rare trapezohedra of quartz.

Now Φ_2 lies almost in the same zone with s and two planes recorded by Des Cloizeaux in his classic memoir on quartz (pp. 107, 118) namely:

$$\Pi = 18.\bar{3}.\ \bar{8} = \tfrac{2}{7}\tfrac{6}{1}P\tfrac{2}{3}\tfrac{6}{1}$$
$$\Phi = 25.\bar{5}.\bar{1}\bar{1} = 1\tfrac{8}{5}P\tfrac{6}{5}$$

The former replaces the edge between u and $3R$ on a crystal from Wallis (fig. 27); the latter replaces the edge between s and an acute rhombohedron to which the symbol $8R$ is ascribed, on a crystal from Wallis (fig. 41); both forms are, it is true, somewhat doubtful, and no numerical measurements are given for the face Φ; it is in fact quite possible that the latter may be identical with Φ_2 of the present crystal.

If Φ_2 belongs to the zone $s\Pi$ it must have the symbol:

$$32.\bar{7}.\bar{1}\bar{4} = \tfrac{4}{1}\tfrac{6}{1}P\tfrac{4}{3}\tfrac{6}{9} = 39.7.\bar{4}\bar{6}.11$$

The angular values corresponding to this symbol are given in the last column of the preceding table and approximate very closely to the observed angles; in fact it is scarcely possible from the above observations alone to distinguish between the two symbols.

Now the measurements are perfectly reliable, both Φ_1 and Φ_2 being bright faces which yield very sharp reflexions. Φ_1 is smooth, and Φ_2 is slightly striated in a direction almost coincident with the edge $\Phi_1\ \Phi_2$.

In order to establish with accuracy the zone $\Phi_1\ \Phi_2$ we may seek to determine the acute rhombohedron which it contains.

Between $3R$, which is a brilliant face, and the prism g_a is an acute rhombohedron Y_1.

$$3R : Y_1 = 12^\circ\ 22\tfrac{1}{2}'$$
$$3R : g_a \quad 14\ \ 2\tfrac{1}{2}' \quad \text{(calculated } 14^\circ\ 42\tfrac{1}{2}'\text{)}$$

further Φ_2 lies in a zone with Φ_1 and Y_1.

Now since the angle $3R : g_a$ differs by $15\tfrac{1}{2}'$ from its calculated value, and the face $3R$ yields the better reflection and is free from striations, we must determine the indices of Y_1 from its inclination to $3R$, disregarding g_a. Hence

$$Y_1 = 18R \qquad 3R : 18R = 12^\circ\ 14\tfrac{1}{2}' \text{ (calculated).}$$

Assuming the indices

$$\Phi_1 = 40.\bar{5}.\bar{1}\bar{7},\ \Phi_2 = 23.\bar{5}.\bar{1}\bar{0}$$

the zone $\Phi_1\ \Phi_2$ contains the rhombohedron $76.\bar{3}\bar{5}.\bar{3}\bar{5} = \tfrac{3}{2}\tfrac{5}{1}R$ which is inclined to $3R$ at the angle $12^\circ\ 16\tfrac{1}{2}'$ and therefore practically coincides with Y_1.

If, on the other hand the indices of Φ_2 are $32.\bar{7}.\bar{1}\bar{4}$ the zone $\Phi_1\Phi_2$ contains the rhombohedron $104.\bar{4}\bar{9}.\bar{4}\bar{9} = \tfrac{5}{2}\tfrac{1}{1}R$ which is inclined to $3R$ at the angle $12^\circ\ 56\tfrac{1}{2}'$.

Hence there can be no doubt that the symbol of the new face is

$$\Phi_2 = 23.\bar{5}.\bar{1}\bar{0}$$

ART. LVII.—*On the Double Chlorides, Bromides and Iodides of Cæsium and Cadmium;* by H. L. WELLS and P. T. WALDEN.

SINCE the cæsium-mercuric halides* had been studied by one of us with the result that six types of double salts were found, it seemed desirable to extend the investigation to the metal cadmium on account of its close relation to mercury. We have, therefore, undertaken this work and as the result of a systematic and very thorough search have obtained the following compounds. The salt Cs_2CdCl_4 had already been described by Godeffroy.

3:1 Type.	2:1 Type.	1:1 Type.
------	Cs_2CdCl_4	$CsCdCl_3$
Cs_3CdBr_5	Cs_2CdBr_4	$CsCdBr_3$
Cs_3CdI_5	Cs_2CdI_4	$CsCdI_3.H_2O$

These cadmium salts correspond to the three types of mercuric compounds which contain the largest proportion of cæsium, and no evidence of the existence of cadmium double halides analogous to the 2:3, 1:2, and 1:5 types of cæsium-mercuric salts could be obtained. It is evident that the tendency to form a variety of double halides decreases from mercury to cadmium.

Three types of cadmium double halides with alkali metals and ammonium have been previously described, and a list of these is as follows:

4:1 Type.	2:1 Type.	1:1 Type.
$(NH_4)_4CdCl_6$	$(NH_4)_2CdCl_4.H_2O$	$KCdCl_3.\frac{1}{2}H_2O$
K_4CdCl_6	$Na_2CdCl_4.3H_2O$	$NaCdBr_3.2\frac{1}{2}H_2O$
$(NH_4)_4CdBr_6$	K_2CdCl_4	$KCdBr_3.\frac{1}{2}H_2O$
K_4CdBr_6	$K_2CdCl_4.H_2O$	$NH_4CdBr_3.\frac{1}{2}H_2O$
	$(NH_4)_2CdI_4.2H_2O$	NH_4CdF_3
	$Na_2CdI_4.6H_2O$	
	$K_2CdI_4.2H_2O$	

It is noticeable that, while the 2:1 and 1:1 salts in the above table correspond to two types of the cæsium salts which we have prepared, the 4:1 type of ammonium and potassium compounds differs from our 3:1 cæsium-cadmium salts and from the corresponding cæsium-mercuric compounds. We were entirely confident that our results were correct, for the salts were well crystallized and carefully prepared for analysis, and it was impossible to believe that we had obtained too little

* This Journal, III, xliv, 221.

cæsium in our analyses, because the salts of this type were crystallized from solutions containing a large excess of cæsium halide. In order to convince ourselves that there was no mistake about the 4 : 1 formulæ we have prepared the two chlorides according to the directions of von Hauer who described them. The salts were extremely well crystallized and it was easy to obtain them in a very pure condition. The results of the analyses were as follows :

	Found.		Calculated for K_4CdCl_6.
Potassium	32·35	....	32·49
Cadmium	23·39	23·36	23·27
Chlorine	44·00	44·12	44·24

	Found.		Calculated for $(NH_4)_4CdCl_6$.
Ammonium	18·20	....	18·12
Cadmium	27·91	27·87	28·22
Chlorine	53·50	....	53.66

These results confirm von Hauer's formulæ, and the curious fact must be accepted that cæsium forms 3 : 1 double halides with cadmium, while potassium and ammonium form salts of the 4 : 1 type.

The four types of cadmium double halides now known form a very simple and symmetrical series, the ratios of the alkali-metal to cadmium being 4 : 1, 3 : 1, 2 : 1 and 1 : 1. The first two of these types do not conform to Remsen's so-called law* concerning the composition of double halides.

Preparation and General Properties.—The compounds to be described were prepared by making warm solutions of the component halides, and after concentrating if necessary, cooling to crystallization. Water, slightly acidified with the corresponding acid to prevent the formation of basic compounds, was used as the solvent, and in one instance, where a solution became syrupy from a large excess of a cadmium salt, alcohol was also tried, but without any advantage. The conditions were varied gradually in each case all the way from the point where the solution was saturated with the cæsium halide to the point where it was saturated with the cadmium halide, and so many experiments were made that we believe that no double salt, capable of existence at the temperatures used, was overlooked. It was noticed that variations in the concentration of any given solution had little effect upon the identity of the salt produced. In this respect the cadmium compounds differ considerably from those of mercury, for with the latter,

* Am. Chem. Jour., xi, 291.

concentration is often an important factor in determining the salt produced.

The three 1:1 compounds $CsCdCl_3$, $CsCdBr_3$ and $CsCdI_3 . H_2O$ and also the 2:1 iodide Cs_2CdI_4 are capable of being recrystallized from water unchanged. The salt Cs_2CdCl_4, when dissolved in water, yields $CsCdCl_3$, the two bromides Cs_2CdBr_5 and Cs_2CdBr_4 yield $CsCdBr_3$ while the iodide Cs_3CdI_5 gives Cs_2CdI_4. These facts show that the salts having the larger proportions of cæsium require the presence of an excess of cæsium halide for their formation. The 1 : 1 salts all crystallize unchanged from extremely concentrated solutions of the corresponding cadmium halides.

All the salts are colorless. A pale violet color noticed in a few crops of the bromide Cs_2CdBr_4 is supposed to have been due to some unknown foreign substance.

The solubility of the analogous salts in water or in saline solutions evidently increases from the chlorides to the iodides. The iodides consequently yield the largest crystals while the chlorides give the smallest.

Methods of Analysis.—The products were carefully examined, and nothing was analyzed that was not homogeneous. The crystals, which, in several instances, were large and fine and in no case hygroscopic, were freed from mother-liquor with great care by pressing and crushing them on smooth filter-paper. They were then simply air-dried for analysis.

Cadmium was precipitated as sulphide, this was dissolved in hydrochloric acid containing bromine, and after the free acid had been removed by evaporation, the cadmium was precipitated with potassium carbonate solution and cadmium oxide was weighed on a Gooch filter. The cæsium in the filtrate from the cadmium sulphide was determined as normal sulphate. The halogens were determined in separate portions by the usual gravimetric method.

In every case, at least two separate crops of a salt were made and analyzed, so as to avoid any chance of mistakes arising from mixtures.

2 : 1 Cæsium-Cadmium Chloride, Cs_2CdCl_4.—This salt is produced as a precipitate when a solution of cadmium chloride is added to a concentrated cæsium chloride solution. The precipitate dissolves upon warming the liquid, and crystallizes out in very small, rectangular plates when the solution is cooled. Its formation was observed when 50^g of cæsium chloride and 3^g of cadmium chloride were used, and it continued to be produced with the same amount of cæsium chloride until the amount of cadmium chloride had been increased to 18^g, at which point the 1 : 1 salt began to form. The salt is very sparingly soluble in cæsium chloride solutions

and it is probably due to this fact that no chloride of the 3 : 1 type could be obtained.

Three separate crops gave the following results on analysis :

	Found.			Calculated for Cs_2CdCl_4.
Cæsium	51·55	51·26	51·51	51·35
Cadmium	21·45	21·50	----	21·62
Chlorine	27·03	27·14	26·90	27·03
	100·03	99·90		100·00

1 : 1 Cæsium-Cadmium Chloride, $CsCdCl_3$. — This was obtained only as a white crystalline powder. It is formed under a very wide range of conditions, being produced by the recrystallization of the preceding salt, and continuing to appear until the solution is saturated with cadmium chloride. It is very difficultly soluble, especially in concentrated cadmium chloride solutions, and it can be recrystallized unaltered from water. Two samples, obtained under widely different conditions, were analyzed.

	Found.		Calculated for $CsCdCl_3$.
Cæsium	38·11	37·60	37·84
Cadmium	31·80	31·97	31·86
Chlorine	30·17	30·25	30·30
	100·08	99·82	100·00

3 : 1 Cæsium-Cadmium Bromide, Cs_3CdBr_5. — This compound was obtained in the form of rectangular plates, sometimes as much as 10^{mm} in diameter. It can be made from a solution of 80^g of cæsium bromide and $4{\cdot}5^g$ of cadmium bromide in sufficient water to make a volume of 120^{cc}. On recrystallization it gives $CsCdBr_3$.

Two separate samples were analyzed.

	Found.		Calculated for Cs_3CdBr_5.
Cæsium	44·25	44·27	43·80
Cadmium	11·88	----	12·29
Bromine	43·79	43·77	43·91
	99·92		100·00

2 : 1 Cæsium-Cadmium Bromide, Cs_2CdBr_4.—This was obtained in the form of slender needles, usually colorless, but sometimes possessing a pale violet color for some unknown reason. A solution 120^{cc} in volume, containing 3^g of cadmium bromide and 52^g of cæsium bromide gave this salt. When recrystallized from water, it gives, like the preceding salt, the compound $CsCdBr_3$.

The following analyses of separate crops were made. No. IV was a simple of the pale violet variety.

	Found.				Calculated for
	I.	II.	III.	IV.	Cs_2CdBr_4.
Cs	40·46	40·53	....	40·46	38·11
Cd	14·55	14·62	14·68	14·78	16·05
Br	45·12	44·97	45·04	45·04	45·84
	100·13	100·12		100·28	100·00

Although the analyses agree well among themselves, it is noticeable that they vary considerably from the calculated composition. This disagreement is probably due to contamination with cæsium chloride, resulting from the large surface exposed by the slender crystals and the concentration of the mother-liquor. Moreover, analogy with the chloride and iodide makes the simple formula Cs_2CdBr_4 far more probable than the complicated formula $Cs_7Cd_3Br_{13}$ with which the analyses correspond.

1 : 1 Cæsium-Cadmium Bromide, $CsCdBr_3$.—The conditions under which this compound is formed are very wide in range, for it is produced by recrystallizing Cs_3CdBr_5 and it continues to appear as cadmium bromide is added until the solution is saturated with this very soluble salt.

The compound is evidently dimorphous. One form occurs as a crystalline precipitate, apparently isometric in form, under narrow limits of conditions when cæsium bromide is in excess, being produced when Cs_3CdBr_5 is recrystallized from water. The other form occurs in well crystallized prisms, and is obtained when Cs_2CdBr_4 is recrystallized and when cadmium bromide is in excess of this proportion. It is interesting to notice that we have described a cæsium-lead bromide* of this type, $CsPbBr_3$, which is dimorphous, and that one of us has described the dimorphous mercuric compounds,† CsHgCl, and $CsHgBr_3$, which also belong to the same type.

Below are the analyses of four separate samples. Number IV is the granular, isometric salt, the others represent the prismatic compound.

	Found.				Calculated for
	I.	II.	III.	IV.	$CsCdBr_3$.
Cs	27·67	27·48	....	27·95	27·42
Cd	22·97	23·08	22·87	22·92	23·09
Br	49·49	49·42	49·33	49·30	49·49
	100·13	99·98		100·17	100·00

*This Journal, xlv, 128. †Ibid., xliv, 225 and 228.

3 : 1 Cæsium-Cadmium Iodide, Cs_3CdI_5.—This salt crystallizes beautifully in large, stout, twinned prisms which show a variety of habits. Some of the crystals obtained were as much as 50^{mm} in diameter. Its formation was observed when 182^{g} of cæsium iodide and 6·5^{g} of cadmium iodide were dissolved in sufficient water to make a volume of 200^{cc}.

Four crops gave the following results on analysis:

	Found.				Calculated for Cs_3CdI_5.
Cs	34·85	34·89	34·78	----	34·82
Cd	9·78	9·79	9·84	9·55	9·77
I	55·23	55·35	55·32	55·36	55·41
	99·86	100·03	99·94		100·00

2 : 1 Cæsium-Cadmium Iodide. Cs_2CdI_4. — This, like the corresponding mercuric salt, crystallizes in nearly square plates, in prisms and in intermediate forms. Some of the plates obtained were 50 or 75^{mm} in diameter. It can be prepared by recrystallizing Cs_3CdI_5 from water, and as the proportion of cadmium iodide is increased, it continues to form until the ratio of cadmium to cæsium has almost reached 1 : 1. The range of its formation is, therefore, much greater than that of the corresponding chloride and bromide, and it also differs from these in being recrystallizable from water. Three different samples were analyzed.

		Found.		Calculated for Cs_2CdI_4.
Cæsium	29·85	30·29	30·23	30·03
Cadmium	12·56	12·53	12·46	12·64
Iodine	----	57·27	57·42	57·33
		100·09	100·11	100·00

1 : 1 Cæsium-Cadmium Iodide, $CsCdI_3 . H_2O$. — This salt forms thin plates, often 20 to 30^{mm} in diameter. It is the only hydrous cæsium-cadmium halide that we have obtained, and it is stable when exposed to the air at ordinary temperatures.

It was considered doubtful whether the corresponding cæsium mercuric iodide* contained a molecule of feebly combined water or not, but since both the cadmium and mercuric salts crystallize in thin plates, it is now believed, from analogy, that the mercuric compound was really hydrous.

The compound under consideration is formed under wide limits of conditions when the cadmium present is atomically equivalent to or in excess of the cæsium. It can be recrystallized from water. The samples analyzed were prepared under widely varying conditions.

* This Journal, xliv, 230.

	Found.		Calculated for $CsCdI_3 . H_2O$.
Cæsium.....	20·89	20·75	---- 20·66
Cadmium	17·13	17·43	17·89 17·39
Iodine	59·21	59·18	---- 59·16
Water.....	2·88	2·80	2·76 2·79
	100·11	100·16	100·00

Sheffield Scientific School,
New Haven, Conn., August, 1893.

ART. LVIII.—*On the Double Chlorides, Bromides and Iodides of Cæsium and Zinc, and of Cæsium and Magnesium;* by H. L. WELLS and G. F. CAMPBELL.

THE cæsium-mercuric and the cæsium-cadmium halides have already been studied in this laboratory, and it has seemed desirable to extend the investigation to the zinc and magnesium compounds, thus completing the study of the cæsium double halides of this family of bivalent metals as far as the chlorides, bromides and iodides are concerned.

We have obtained the following salts:

3 : 1 Type.	2 : 1 Type.	1 : 1 Type.
Cs_3ZnCl_5	Cs_2ZnCl_4	?
Cs_3ZnBr_5	Cs_2ZnBr_4	?
Cs_3ZnI_5	Cs_2ZnI_4	?
------	------	$CsMgCl_3 . 6H_2O$
------	------	$CsMgBr_3 . 6H_2O$
------	------	--------

A systematic and thorough search has been made in all cases, and it is remarkable that while mercury gave six types of cæsium double salts and cadmium gave three, only two could be obtained with zinc and one with magnesium. It is evident that the variety of these double salts increases with the atomic weight of the bivalent metal. The existence of zinc salts of the 1 : 1 type is suspected, but the suspected products were obtained only in extremely concentrated zinc halide solutions of such a syrupy nature that no satisfactory analyses of them could be made.

The previously described double halides of zinc and magnesium with the alkali-metals, as far as we have been able to find them, are given below:

3 : 1 Type.	2 : 1 Type.	1 : 1 Type.
$(NH_4)_3ZnCl_5$	$(NH_4)_2ZnCl_4$	$NH_4ZnCl_3 . 2H_2O$
	$(NH_4)_2ZnCl_4 . H_2O$	$KZnI_3$
	$Na_2ZnCl_4 . 3H_2O$	$NaZnI_3 . 1\frac{1}{2}H_2O$
	K_2ZnCl_4	$NaZnF_3$
	$(NH_4)_2ZnBr_4$	$KZnF_3$
	$(NH_4)_2ZnI_4$	$NH_4MgCl_3 . 6H_2O$
	$Na_2ZnI_4 . 3H_2O$	$NaMgCl_3 . H_2O$
	K_2ZnI_4	$KMgCl_3 . 6H_2O$
	K_2ZnF_4	$RbMgCl_3 . 6H_2O$
	$(NH_4)_2ZnF_4 . 2H_2O$	$NH_4MgBr_3 . 6H_2O$
		$KMgBr_3 . 6H_2O$
		$NH_4MgI_3 . 6H_2O$
		$KMgI_3 . 6H_2O$
		$NaMgF_3$

There is but a single 3 : 1 salt, corresponding to our new cæsium compounds of that type. This was described by Marignac. A few 1 : 1 zinc salts have been described, hence it is remarkable that cæsium zinc salts of this type could not be obtained in a pure condition, for previous experience in this laboratory has shown that cæsium usually forms less soluble and more stable double halides than the other alkali-metals. All the previously described magnesium salts belong to the 1 : 1 type* to which our cæsium salts belong, and like the latter nearly all have six molecules of water.

The cæsium-magnesium bromide is formed under narrower limits of conditions than the chloride, while no iodide could be prepared, for cæsium iodide crystallized unchanged from syrupy solutions of magnesium iodide. This behavior was quite unexpected in view of the fact that the ammonium and potassium double iodides are known, and we have here another instance where cæsium, in spite of its usual tendency to form double salts, is inferior in this respect to other alkali-metals. The idea suggests itself that great differences between the atomic weights of the alkali-metal and the less positive metal are unfavorable for the formation of double salts, but more facts will be necessary in order to establish such a rule.

The cæsium-magnesium salts show an increase in ease of formation from the iodide to the chloride. Such a gradation, both in variety of salts and ease of preparation, is evident in a number of series of double halides which have been studied in this laboratory, and the well known tendency of fluorides to form double salts indicates that the gradation probably extends to these compounds.

* Lerch has shown (J. Pr. Ch., II, xxviii, 338) that the salts $2KBr . MgBr_2 . 6H_2O$ and $2NH_4Br . MgBr_2 . 6H_2O$ of Löwig do not exist.

3 : 1 Cæsium-Zinc Chloride, Bromide and Iodide, Cs_3ZnCl_5, Cs_3ZnBr_5 and Cs_3ZnI_5.—Each of these salts crystallizes in colorless prisms, apparently monoclinic in form. They are produced by making aqueous solutions of the constituents in the calculated proportions, but in the case of the iodide, with these proportions the 2 : 1 salt may form if the solution is too dilute. The salts under consideration continue to form as the relative amounts of cæsium halides are increased until the latter crystallize upon them. This indicates that no double salts with a higher proportion of cæsium exist. The iodide forms under rather wider limits of conditions than the other two salts and it usually forms larger crystals. All the salts require concentrated cæsium halide solutions for their preparation, and the chloride especially is difficult to obtain in sufficient quantity for analysis unless as much as one or two hundred grams of the cæsium halide is used. The following analyses were made, all of which represent separate crops.

	Found.		Calculated for Cs_3ZnCl_5.
Cæsium	62·46	----	62·20
Zinc	10·08	9·80	10·13
Chlorine	27·43	27·34	27·67

	Found.		Calculated for Cs_3ZnBr_5.
Cæsium	47·12	---- ----	46·18
Zinc	7 32	7·54 7·87	7·52
Bromine	45·91	46·54 45·85	46·30

	Found.		Calculated for Cs_3ZnI_5.
Cæsium	36·54	36·20 36·08	36·30
Zinc	5·77	5·95 5·74	5·92
Iodine	56·89	57·16 ----	57·78

2 : 1 Cæsium-Zinc Chloride, Bromide and Iodide, Cs_2ZnCl_4, Cs_2ZnBr_4 and Cs_2ZnI_4.—These salts form colorless plates, decreasing in size from the iodide to the chloride. They are all readily produced when larger proportions of the zinc halides are used than are necessary for the 3 : 1 compounds and they recrystallize from water unchanged. They continue to form, through a wide range of conditions, as more of the zinc halides are added until the solutions become syrupy. In extremely syrupy solutions crystals of a different appearance were noticed, but on account of the nature of these solutions, no satisfactory analyses of these products could be made. It seems probable that they were 1 : 1 salts, analogous to the cadmium salts of that type.

The following analyses of separate crops were made:

	Found.		Calculated for Cs_2ZnCl_4.
Cæsium	55·97	56·09	56·26
Zinc	13·49	13·87	13·72
Chlorine	29·89	29·97	30·02

	Found.		Calculated for Cs_2ZnBr_4.
Cæsium	40·68	....	40·86
Zinc	9·53	9·72	9·98
Bromine	49·30	49·17	49·16

	Found.		Calculated for Cs_2ZnI_4.
Cæsium	31·49	31·55	31·70
Zinc	7·61	7·82	7·75
Iodine	60·43	....	60·55

Cæsium-Magnesium Chloride and Bromide, $CsMgCl_3 . 6H_2O$ and $CsMgBr_3 . 6H_2O$.—These salts form colorless, rectangular plates or flat prisms which are often striated. A thorough search gave no indications of salts of other types. The chloride is formed under a wide range of conditions, the bromide under a much narrower range while no double iodide at all could be prepared.

The following analyses were made of separate products:

	Found.				Calculated for $CsMgCl_3 . 6H_2O$.
Cs	37·14	....	35·66	....	35·77
Mg	6·80	....	....	6·83	6·53
Cl	29·84	30·13	29·70	29·55	28 65
H_2O	....	30·93	....	....	29·05

	Found.			Calculated for $CsMgBr_3 . 6H_2O$.
Cs	27·23	27·67	....	26·32
Mg	4·96	4·50	5·07	4·81
Br	48·93	48·65	....	47·51
H_2O	18·32	....	22·33	21·37

It should be mentioned that Dr. H. L. Wheeler of this laboratory has attempted to prepare a double chloride of cæsium and beryllium. He found that the simple salts crystallized side by side from sufficiently concentrated solutions, and there were no indications of the existence of any double salt, even at rather low temperatures. It is therefore evident that beryllium follows the rule, already indicated, that in this family of bivalent elements, Be, Mg, Zn, Cd, Hg, the tendency to form double halogen salts increases with their atomic weights.

Sheffield Scientific School.
New Haven, Conn., August, 1893.

ART. LIX.—*New fossil localities in the early Paleozoics of Pennsylvania, New Jersey and Vermont, with remarks on the close similarity of the lithologic features of these Paleozoics;* by AUG. F. FOERSTE.

[Published by permission of G. K. Gilbert, Chief Geologist U. S. Geological Survey.]

THE general distribution and succession of the paleozoic rocks of New Jersey, east of the Kittatinny Mountains and west of the Green Pond Mountain ranges and of the more southern part of the Triassic area, were clearly understood by the former State geologist George H. Cook and his assistants, at an early date. The folding to which this territory had been subjected was too simple, structurally, not to be easily unravelled. Immediately below a great conglomerate series on the eastern side of the Kittatinny Mountains, now known as the Oneida conglomerate, lay a great mass of sandy shales, or slates, constituting the Hudson River shale horizon. Below this was a great thickness of limestones, generally whitish in color, from which fossils were known at an horizon, lithologically somewhat distinct. This horizon consisted of a bluish, at times dark blue limestone, at the very top of the limestone group, just underneath the shales, and almost always contained fossils. To find fossils at this horizon it is only necessary to follow the trend of the formation and to keep a sharp lookout. The fossils are often small, but were early identified as Trenton. The white, often magnesian, limestones beneath, composing almost all of the limestone series were clearly separable from the Trenton horizon, as a Magnesian series. No fossils were found and so their age was properly left a little indefinite, except as regards their pre-Trenton character. Beneath the limestones, a sandstone belt of moderate thickness was known to be almost universally present. As sandstones at the base of the paleozoic series were then understood, it was possible to interpret this basal sandstone only as Potsdam, a lithological interpretation, which since has lost its value. Beneath this sandstone occurred crystalline rocks, white limestone, gneisses, massive granites, and dykes, but except in northern Sussex county, no igneous rocks were known to penetrate the paleozoic series, and even there such penetration was limited to certain dike rocks, with limited contact metamorphism. These rocks were called Archæan. Some who are at present working in this field suspect that a part of these rocks will have to be eventually classed as Algonkian but that is a new

discrimination, and was one not to be expected of the older survey.

The work of the older New Jersey survey will therefore practically stand. It is a matter of regret that on the later published geological maps, the Trenton horizon and the so-called Potsdam were not designated by separate colors. But the survey was eminently an economical one, and these horizons representing narrow outcrops of no practical value, and being universally present, where surface deposits did not obscure the geology, and their outcrops being parallel to the upper and lower limits of the limestone series, they offered no inducement to separate mapping on a map with the small scale of five miles to the inch; moreover the expense of printing would have been greatly increased. The more recent discoveries in this region are therefore not so radically new as at first sight might appear to be the case, but they are important from the point of view of paleontologic stratigraphy. They did not change the stratigraphy but they affected the terminology of the lower of the beds here considered.

While Mr. Nason was studying the White Limestone region of Sussex County, New Jersey, he had the assistance of Dr. C. E. Beecher in the paleontological part of the work. Dr. Beecher found trilobites—Olenellus—in the sandstone at Hardistonville (with Scolithus) (5) and also in the sandstone about a mile south of here at a point near locality 7 on the accompanying map, and Mr. Nason himself, found a fragment of a trilobite, presumably Olenellus, near Franklin Furnace, but in his section XIV the exact locality is not indicated. Dr. Beecher also found a species of Obolella in what are very probably the *lower* parts of the Magnesian limestone series in the old furnace quarry north of the western half of Franklin Furnace Pond; and fossils were also found by him in "the unchanged blue limestone" (Nason) stratigraphically above the Olenellus sandstone at Hardistonville.*

As a result of these observations the basal part of the Magnesian limestones (and also the white limestone according to Mr. Nason's views of correlation) and the sandstone here formerly called Potsdam were ascribed to the Olenellus horizon.

Mr. Nason was especially engaged in the study of the white limestones. Consequently he did not follow up the outcrops of the Olenellus sandstone very closely, as is indicated by various omissions within the range of his published map, and by the outlining of various sandstone outcrops. He did not

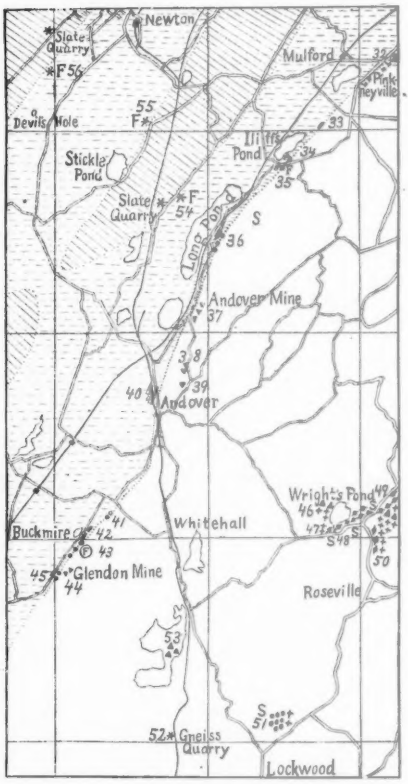
* Ann. Rep. of State Geol. of New Jersey, 1890—The Post-Archæan Age of the White Limestones of Sussex County, N. J., by Frank L. Nason, pp. 31, 43, 55, 46, 49, sections X, XIII, XIV.

work his way far enough out of the metamorphic white limestone region to see that his discoveries necessitated the relegation of all the so-called Potsdam sandstones and basal Magnesian limestones and these alone to the Olenellus horizon. This is shown by his final conclusions that a careful search for fossils must be made "in the whole belt, or rather belts of limestones, sandstones, slates, and shales hitherto called and regarded as Potsdam, *Trenton*, and *Hudson River*" (italics not in the original. See pages 49, 50 of the Report.)

When the writer was called into New Jersey by the needs of the survey of the Archæan Highlands under the more immediate charge of Prof. J. E. Wolff and his assistant, Mr. R. S. Tarr, his first duty was to trace the Cambrian sufficiently out of the metamorphic area to determine what was Pre-Cambrian and the second was to investigate the doubts recently thrown upon the previous determinations of Trenton and Hudson River strata.

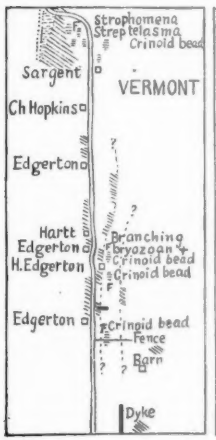
The last was quickly solved by an irregular section from the Archæan at Andover to the Oneida conglomerate of the Kittatinny Mountain range at Culver's Gap. The thin blue limestone overlying the Magnesian limestones and underlying the Hudson River was found to everywhere contain fossils, such as are found in Trenton rocks. In the thin blue limestones of this section fossils were for instance found on the eastern side of the road running north about half a mile west of Long Pond, and some distance north of an old slate quarry, on the eastern side of a synclinal (54). Also on the western side of this synclinal, directly west of a strong bend in the road almost half a mile north of Stickle Pond (55). Again on the eastern side of the next synclinal, three-eighths of a mile directly south of the great slate quarries a short distance southwest of Newton (56). This exposure is in a field, on the eastern slope of the hills. Also on the western side of this second synclinal, along the New York, Susquehanna & Western railroad track a short distance south of Augusta, at a curve in the railroad. Finally, half a mile east-northeast of Branchville, where this limestone finally disappears under the Hudson River, so as not to appear again in western New Jersey.

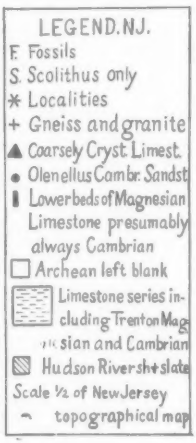
Parts of the first task were equally easy owing to the simplicity of the strike and dip of the Olenellus sandstone which varies too little from outcrop to outcrop to make it difficult to trace the formation. Moreover in most of the outcrops in the fairly continuous line of exposures between Hardistonville (5) and the locality two miles southwest of Franklin Furnace (15), fossils are very abundant in certain layers of the sandstone, so that they are very readily found. Their locations are sufficiently indicated in the accompanying map. Fossils are

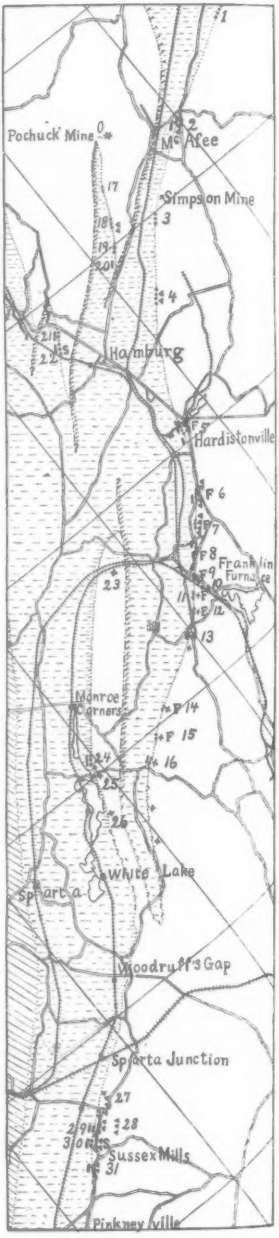


Northern Part
Southern Part

Map of fossiliferous Olenellus Cambrian outcrops in Sussex County, New Jersey.




LEGEND. NJ.
F Fossils
S. Scolithus only
* Localities
+ Gneiss and granite
▲ Coarsely Cryst. Limest.
• Olenellus Cambr. Sandst
Lower beds of Magnesian Limestone presumably always Cambrian
Archean left blank
Limestone series including Trenton Magnesian and Cambrian
Hudson River shale
Scale ½ of New Jersey topographical map



again found at various points along the line of outcrops extending from the road corner south of Sparta Junction (29) to a point about half way between Andover and Tranquility (45). These exposures are also sufficiently well located on the accompanying map. But along this second line, fossils, except Scolithus, are rare, and the decisive locality is the one carrying Olenellus and other fossils at the strong bend in the road southeast of Iliff's Pond, as the pond northeast of Long Pond is called (35). At the various localities examined Olenellus was found at 5, 6, 7, 8, 9, 11, 12, 14, 15, and 35. A trilobitic fragment resembling Ptychoparia was found at 43. Species of Hyolithes were also seen, one resembling *H. Americanus*, at 11, and another resembling *H. communis*, at 14. Various forms of the burrowed tubes known as Scolithus were very common at many localities; they were found at 5, 8, 9, 11, 14, 15, 22 (rare), 30, 35 on the hillside between 35 and 36, 51, and in the reddish siliceous limestones, weathering at times to shale, and in the intercalated sandstones at 48, 49, and 50.

Any one at all closely observant will notice at once that even in this limited area the Scolithus burrows were not all made by the same species of animal. In the fine grained siliceous limestones near Wright's Pond, 48, 49, 50, the burrows are narrower, usually 2^{mm} in diameter or less, and closer together and reach a length of 60^{mm}, or more, and they are nearly straight and vertical to the bedding. This form is also found in rocks of similar lithological character in some of the exposures between Andover and Hardistonville. It was evidently a somewhat more gregarious species than the ordinary form, and preferred muddy bottoms while the ordinary form chose a sandy habitus. A second form resembles the ordinary type in choosing a sandy bottom. It had perhaps slightly larger burrows, about 3^{mm} in diameter, or at times a little larger. Its chief distinction lies however in its burrowing habit, which was not distinctly vertical but the burrows are irregular in direction, as though the animal after having entered the sandy bottom, extended its burrows in a more or less irregularly horizontal direction. It may represent a totally different class of animals from those of the vertically burrowing forms. It has been seen only at 51, near Lockwood, but there it is abundant.

Lithologically the Olenellus Cambrian sandstone can be traced into eastern Pennsylvania, its limited thickness and constant characters throughout this extent with the knowledge that the base of the Magnesian limestone series in New Jersey at least is Cambrian, making it probable that all hitherto called Potsdam in eastern Pennsylvania is now to

be classed as Olenellus Cambrian until fossils are found which will shed further light on the subject. That the lower paleozoic section of northern New Jersey is still preserved in all its features in eastern Pennsylvania is readily seen along the magnificent sections offered by the Lehigh between the Kittatinny range and Bethlehem. Underlying the Oneida conglomerate of Kittatinny Mountain, are the shales and slates of the Hudson River series. The top of the underlying great limestone series is again an especially constant fossiliferous horizon of Trenton age. As in the Vermont localities to be described later, these Trenton fossils occur not only at the top of the limestone series, but also in thin beds of limestone intercalated in the base of the shales referred to as Hudson River. Such intercalated limestones containing Trinucleus and other fossils may be seen toward the base of the shales on the road leading diagonally from North White Hall P. O. on the railroad, southward up hill above the cement works along the track, 2½ miles north of Hockendauqua. Below the limestone series the basal Cambrian sandstone occurs again, of moderate thickness, having here however the character of a quartzite, there being no disintegration, as in most of the New Jersey exposures. The base of the sandstone is distinctly conglomeratic, and rests unconformably upon Archæan gneisses, but with a less marked angle of discordance than in the northern New Jersey exposures. Some of the lower beds of sandstone are tinged with purple, and in these it is not uncommon to find large coarse tubes, burrowed vertically into the sand, varying from 10 to 20^{mm} in thickness and from 70 to 150^{mm} in length, usually filled up with a lighter colored sand than the rock in which they are found, being evidently the same kind of sand as that forming the next higher layer, in each case. The wash of the sea seems to have partly broken down the top margin of the tubes before the filling with sand was completed, the result is a tube of the appearance of *Monocraterion Lesleyi* Prime, found in the basal members of the limestone series, a quarter of a mile northwest of Helfrich's Spring and again in limestone three quarters of a mile northwest of Durham iron works. Although this is a tempting opportunity to conclude that these tube casts indicate the Cambrian character of the basal portions of the limestone series, a fact already known for New Jersey and Vermont, it must be admitted that worm burrows are hardly to be given the value of determinative fossils.

While the New Jersey Survey has always acknowledged the Green Pond Mountain series as a *terra incognita* or at least a region of many unsettled questions, as is evidenced among other things by the coloring it was obliged to employ in its

geological maps, it had nevertheless in later years laid the basis for its solution. East of Newfoundland in the back lots of some of the last houses, on the southeast side of the hill, fairly good and abundant Oriskany fossils had been found *in situ*. A mile and a half south of Newfoundland, where the road crosses the stream, the valley contains at various places large bowlders with Helderberg fossils, suggesting that the northeast, southwest valley here was filled in part by this series. Since the rocks all dip west the coarse conglomerates forming the eastern side of Copperas and Kanouse Mountains must be Oneida, the red sandstone above the same the Medina, the underlying limestone, the Magnesian limestone, and the basal sandstone, Cambrian, but instead of the term Potsdam, it is necessary now, until further development to call it Olenellus Cambrian. It is a quartzitic sandstone, from 10 to 15 feet thick and so far has not furnished fossils. The unconformity indicated by the absence of the Hudson River shales east of Kanouse Mountain, and its increased emphasis southwards, by the additional absence of the Magnesian limestones and the Olenellus Cambrian sandstone, are facts already appreciated at the time of the publication of the Final Report of 1868. That part of the lower paleozoic section which is exposed here, agrees with what has been found farther west, in the area between the Archæan areas and the Kittatinny Mountains.

With these sections as exhibited in New Jersey and eastern Pennsylvania, the Vermont lower paleozoic rocks show a striking similarity. That the sandstones along the western flanks of the Green Mountain area were Olenellus Cambrian was made sufficiently evident by the work of Mr. C. D. Walcott (The Taconic System of Emmons, and the use of the name Taconic in geologic literature.) The Stockbridge limestone of Vermont corresponds to the Magnesian limestone of New Jersey. At its top there is again a thin blue or dark blue limestone bed, occasionally recurring, as in Pennsylvania, as thin beds intercalated in the basal portions of the overlying shales, and containing a Trenton fauna. As in New Jersey, localities for fossils can be multiplied in this horizon almost *ad libitum*. Localities discovered by the writer are mentioned in the publication of Prof. J. E. Wolff (On the Lower Cambrian age of the Stockbridge limestones at Rutland, Vermont, Bull. Geol. Soc. America, vol. ii, 1891), and of Mr. T. N. Dale (On Plicated Cleavage-Filtration, this Journal, vol. xliii, p. 317). But these are only a part of the localities found and none of the more southern ones are given. A few are here appended, the most southern being near Danby Four Corners, making thus a length of twelve miles from

Rutland southwards, in which this thin blue Trenton limestone, usually not exceeding thirty feet in thickness and often much less, is known to occur. At Danby Four Corners one exposure lies about two miles southwest of the town in the fields near woods; a second is seen directly northeast of the corners in the southwestern part of a large open field. Taking the road leading west of South Wallingford to its junction with the west valley road, which follows the eastern side of the long range of hills bounding the western side of the Rutland-South Wallingford Valley, an exposure of this fossiliferous blue limestone can be found by going diagonally up the hill, in a general northwest direction, to a sort of open bench above a more steeply inclined wooded line on the hillside, a considerable distance from the road. Passing from the same junction of the roads northward, a series of exposures are found along the eastern flank of the hill range. Their location is sufficiently shown by the accompanying hasty sketch map. The fossils are few in number, and the geology is complicated by strike faults, and would not be readily understood had the geology not been unravelled by Prof. J. E. Wolff and Mr. T. N. Dale, farther north where it is less complicated. The most interesting locality is that northwest of Sargent's house some distance south of the bend of the road, where the rock shows cross sections of Streptelasma and Strophomena.

Above this Trenton limestone especially west of West Rutland Valley, occurs a great series of shales and sandstones of Hudson River ages, while the coarse conglomerates of Bird Mountain seem to correspond to the Oneida of New Jersey and eastern Pennsylvania sections.

While Dr. Beecher was discovering Cambrian fossils in the basal portions of the Magnesian limestone series in northern New Jersey, the writer, in the summer of 1890, was also finding Cambrian fossils at various points in the Stockbridge limestone north of Rutland, which he also was inclined to view as of Olenellus Cambrian age. Later Prof. Wolff added to these localities. The following year Mr. T. N. Dale found others in the limestones of Center Rutland Valley, west of Clarendon, and the writer later in this second year also collected here, discovering that the Cambrian fossils—chiefly Hyolithes—occurred in a bed having a long strike exposure, and finding a few fossils also below this bed. While these fossils no doubt belong to the lower portions of the great Stockbridge limestone series, yet it is probable that this Cambrian portion extends a considerable distance up into the series, although how far is as yet unknown. At present the writer is more inclined to consider these fossils as very high up in the Olenellus Cambrian, or forming a transition to the Middle Cambrian, but the

fauna is still too meager. The horizon corresponds evidently to the Cambrian portion of the Magnesian beds in New Jersey.

While fossils are not common in the upper or middle portions of the Magnesian limestones in eastern Pennsylvania and New Jersey, or of the Stockbridge limestone in the southern half of Vermont, still they are found. In the publications of the Pennsylvania Geological Survey such localities are mentioned and they occur also in the West Rutland valley both northeast and southwest of the town. The fossils are such as to make evident their Lower Silurian character. They are found beneath the thin dark blue Trenton limestone. So their general reference to the Chazy-Calciferous is warranted (J. D. Dana, An account of the discoveries in Vermont geology of the Rev. Augustus Wing, this Journal, 1877). The basal portions of the Hudson River formation at West Rutland and elsewhere in southern Vermont is often represented by dark, black shales of that peculiar lithological character which at once suggests the presence of graptolites but these have so far not been discovered. In New Jersey, however, the writer is informed by Prof. J. C. Smock, the State Geologist, that graptolites were found by Dr. C. E. Beecher along the railroad track between Pattenburg and Midvale. Near Hoosick, New York, graptolites occur at the same horizon (C. D. Walcott, The Taconic System of Emmons). They will probably be found some time in Vermont.

The chief difference between the lower paleozoic sections in the southern half of Vermont between the Taconic and Green Mountain areas, and those of New Jersey and Pennsylvania lie in the fact that in Vermont the typical Olenellus sandstone, besides being thicker, overlies a considerable thickness of other sandstones, and conglomerates, evidently belonging to the same geological unit, but of which, in the absence of fossils, the precise age cannot be definitely determined. In other respects the correspondence is striking, necessitating the belief that both regions have passed through a closely similar geologic history, and as such might be said to belong to the same geologic province, that Atlantic province extending of course much farther south than eastern Pennsylvania. This similarity is the more striking owing to the dissimilarity from this simplicity of lithologic structure in regions farther north and west and southwest than the various Rutland Valley belts of southern Vermont, as here discussed. This can be partly accounted for by the fact that the Adirondacks in earlier paleozoic times formed a separate source of sediments, and surrounded themselves by a series of rocks whose lithological characteristics are somewhat at variance with those deposited at a greater distance. The sphere of their influence extended into northwestern Vermont,

and for a considerable distance southwards in western Vermont and eastern New York. It is probably in part for this reason that the geology of Rensselaer and Washington Counties is so difficult to unravel and no longer presents the same simplicity of lithologic structure found east of the Taconic range. Lithologically this difference consists in the introduction of argillaceous and sandy limestone, shale and sandstone elements into that part of the early paleozoic scale which is represented in New Jersey and southward by the Magnesian limestone, and in the southern half of Vermont by the Stockbridge limestone, in other words that part of the section between the Hudson River (including for the present the Trenton limestone in the great limestone series) and the top of the Olenellus Cambrian sandstones. How far southward the sphere of influence of the Adirondack sedimentation extended, is unknown. To what extent, the Archæan of the Highland region between Newburgh and Peekskill supplied sediments to the early paleozoic series as here discussed is also still undetermined. The remarkable agreement between the southern Vermont and the New Jersey, eastern Pennsylvania, and more southern sections and the great longitudinal extent of the area having this structure would however lead to the conclusion that these sections represented the main lithologic features of eastern early paleozoic geology; a basal Cambrian sandstone, overlain by a great series of limestones embracing a considerable vertical range of faunas, and a great mass of Hudson River slates and shales and sandstones, overlain finally with more or less unconformable Oneida conglomerate, the unconformability in many places being more theoretic than evident structurally, while in others it is also strongly marked structurally, and always paleontologically. Variations from this lithological type would seem to be due more to local features, sometimes of vast influence as in the case of the Adirondacks, at other times of more limited range. To study out these more local influences as something distinct from the general, to discover their source and their range is a part of the geology of the immediate future.

The various questions of correlation here discussed are of course not new. They are here brought out again chiefly to emphasize the strong agreement between the sections of the early paleozoics in the southern half of Vermont between the Taconic and Green Mountain ranges, and those of New Jersey, eastern Pennsylvania and southwards, an agreement the more remarkable since closely contiguous areas west of the Taconic ranges, in western Vermont, and Massachusetts, and in eastern New York do not show the same simplicity of lithologic structure.

ART. LX.—*An apparent Time-break between the Eocene and Chattahoochee Miocene in Southwestern Georgia;* by RAPHAEL PUMPELLY.

THROUGH the southwestern part of Georgia and adjacent northern Florida there extends a plateau known as the Red Clay hill region. It has a maximum altitude approximately 300 feet above the sea, and an undulating surface, with the main drainage channels cut, with steep cross profiles, to a depth of over 100 feet.

This plateau is sharply limited on the north by an often steep declivity facing the Eocene flat-land country, and consists of Miocene deposits resting on Eocene, both of which dip about 13 feet to the mile to the South. The section along the Flint River where it is cut into the flat-land country, exposes the limestone and siliceous Eocene beds abounding in Vicksburg fossils. Of these Mr. Foerste writes me, that they form "a varied fauna, including species of Operculina, Orbitoides, many corals, Cidaris, Echinocyamus, Clypeaster, Scutella, Lunulites, Ostrea, Pecten, Amusium, Spondylus, Plicatula, Cardium, Turritella, Vermetus, Xenophora, Natica, (Ampulina), Cerithium, Strombus, Cypræa, Cassidaria (Sconsia), Fulgur, Conus and fragments of claws of crabs; among these species Echinocyamus parous, Eumnus, Scutella Lyelli, Pecten Poulsoni, and unknown species of Pectunculus and Cerithuum may be mentioned as especially characteristic of the Vicksburg horizon in Southwestern Georgia."

Where the Flint River cuts through the plateau at an altitude of 40 to 50 feet above the sea, it exposes the white calcareous beds of the Chattahoochee group, but without any visible contact with the underlying Eocene. As has been shown by Mr. Langdon,* the river bank is occupied by the Chattahoochee formation until its gentle southerly dip brings its upper surface below water, and under the Chipola Miocene group at Alum Bluff.

The base of the plateau is Chattahoochee. The exposures in sides of deep ravines and freshly eroded gullies in the plateau almost uniformly show only more or less sandy clays, which in the higher parts seem to be more sandy, and contain smooth pebbles of sandy iron-ore, which may be either clastic or concretionary, and also frequent pebbles of quartz, clearly derived from metamorphic schists. These quartz pebbles are often $\frac{3}{4}$ to $1\frac{1}{2}$ inches long by $\frac{1}{2}$ inch broad, with a thickness of only $\frac{1}{12}$ to $\frac{1}{8}$ inch, and so angular that it is difficult to believe

*Some Florida Miocene, this Journal, October, 1889. Variations in the Cretaceous and Tertiary Strata of Alabama, Bull. Geol. Soc. Am., vol. ii, July, 1891.

that they have been transported very far. The only light obtained thus far as to the age of the upper part of the plateau is found in extensive areas of residuary fossiliferous angular fragments, representing broken-up siliceous beds. These occur at numerous points on the plateau at altitudes of 230 to 260 feet above the sea, and seem to belong below the ferruginous sand with iron ore pebbles. These fragments up to several cubic feet in size, are found covering the surface in areas of many acres in extent, and also imbedded in the underlying clays. At one locality, which we were accustomed to call Gasteropod gully, near Roseland plantation, southeast of Bainbridge, the range exposed between the fragments on the surface, and those in the clays in the adjacent gullies is as much as 60 feet or more, although under the circumstances the true relation between the upper and lower fragments is not apparent. These fragments consist of silicified beach-worn shells which either make up almost the whole rock or are imbedded in the sandstone. The fossils are of Chipola Miocene Age. Of these Mr. Foerste sends me the following list from his determinations.

"Ostrea divaricata, var., Pecten Madisonianus Arca idonea, Carditamera? protracta, Venus mercenaria, var., Strigilla flexuosa, Mactra subcuneata, Solen ensis, Conus planiceps, Drillia similar to lunata, Melongena similar to subcoronata, Typhis acuticostata, var. typhis similar to gracilis, Turritella gatunensis, Turritella with an ornamentation similar to T. acropora, but shell is larger, T.? terebriformis, Solarium bellastriatum, var. Vicksburgense, a moderate variation from the same. Crucibulum auricula var.? imbricatum, Calyptræa centralis, Crepidula fornicata, Natica floridana, Chlorostoma (Omphalius)? exoletum, Helix adamnis, var. Bulimulus? Balanus?

As stated above the surface of the plateau is generally undulating. Wherever it has been exposed to cultivation deep gullies have rapidly cut their way back into it. These facts would incline one to look upon the plateau as a Miocene island area covered and levelled up with a much more recent sand formation. The younger sands may however be of Miocene age like those above the Chipola and Ecphora beds at Alum Bluff. And they may have been continuously protected from erosion by the density of vegetation and the porosity of the rocks which permitted the downward drainage, into subterranean channels, which is still active throughout the region. This last alternative accords with the view expressed by Mr. A. F. Foerste,* that these sands represent the shoreward extension of the Chipola and Chesapeake formations.

The evidence for a time break between the Eocene and Chattahoochee Miocene consists in:

* Chipola Miocene of Bainbridge, Ga., and Alum Bluff, Fla. This Journal, Oct., 1893.

I. The almost general presence of a limestone conglomerate at the base of the Chattahoochee, immediately overlying Eocene fossils. This conglomerate is sometimes a breccia, and often like a rock shattered in place; but more often it consists of clearly rolled pebbles of limestone not distinguishable from the Eocene rock below.

II. The surface of demarcation between the Eocene and Chattahoochee is very irregular. The Eocene rises island-like into the Miocene. The altitude of the contact differs considerably at points but a few miles apart along the strike. Thus the contact is

180 feet above the sea on Griffin's Creek.
102 feet above the sea in Glenn's Well, 2½ miles eastward.
155 feet above the sea in Powell's limesink, still farther east.

Mr. Foerste writes me that the fossils at Griffin's Creek correspond with those found in the upper part of the Chattahoochee, while those at Glenn's Well, and Powell's limesink correspond with those belonging in the lower half of the Chattahoochee.

At numerous points in southwestern Georgia there occur between the Eocene and Chattahoochee, masses of columnar corals chalcedonized. They are not present at the majority of the points of observed contact. Nor has their exact relation to the Eocene or Chattahoochee been observed. Mr. Dall writes me regarding some that I sent him, that they belong at the base of the Miocene. The observations lead me to think that they probably grew during the interval between the Vicksburgh and Chattahoochee, upon the submerged Eocene surface.

Mr. Alexander Agassiz, in "The three Cruises of the Blake," has called attention to the influence of submerged ridges and plateaux upon the growth of organic formations.

It seems possible that during Miocene time the present plateau of southern Georgia was outlined by submerged islands of the Eocene limestone. The Gulf Stream after the creation of the Central American barrier, found its way back to the Atlantic sweeping over southern Georgia and northern Florida, and supplying the food needed to build up the great organic beds of the Chattahoochee and Chipola.

As these grew to the surface they formed islands which would explain the presence of the land shells found in the Bainbridge Chipola, and also the beach-worn character of the Chipola fossils at the same locality. And the lower flat-land country of central Georgia may represent the contemporaneous course of the cold current, carrying less pure water, and less of the nutriment needed to build up organic deposits.

ART. LXI.—*The Rise of the Mammalia in North America;* by HENRY FAIRFIELD OSBORN, Columbia College, New York.

[Continued from page 392.]

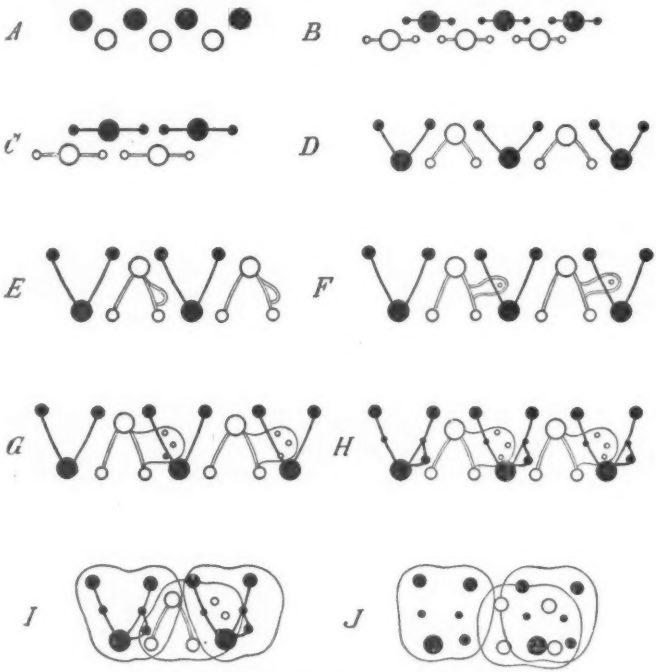
PART II.

Origin and Evolution of Trituberculism.

"CONCRESCENCE" is the newest theory of cusp evolution—an expansion by Kükenthal and Röse of views earlier expressed by Gaudry, Magitot and Dybowski. As Kükenthal derives three conical Cetacean teeth by splitting apart a triconodont molar, he conversely derives a triconodont molar by bringing together three reptile cones. Smith Woodward has called attention to the support the epidermal structures of the fishes give to this hypothesis, yet as applied to mammalian teeth, it comes from a one-sided Morphology which regards only the wonderful though mutilated chapters of Embryology when the untorn pages of Paleontology are at hand. Between the Trias and the Puerco, we are, so to speak, in at the birth of every successive cusp, and can observe positively that the law of cusp evolution is direct upgrowth from the smooth slopes of the crown or from the cingulum, that fertile parent of new cusps. Each new cusp is usually preceded by an abraded surface, and prophesied by an excessively minute hillock. It follows from this that cusps range in size and height directly according to their age—a principle beautifully demonstrated in some of the Mesozoic teeth. If the Kükenthal-Röse theory were correct, the oldest triconodonts should be iso-conid, whereas we know that the three equal cones of Triconodon are all a very late development; the earlier forms show the lateral cones receding to the needle-points of Dromatherium.

The tritubercular molar owes its survival to the original advantage of its triangular form, and to the possibilities of free cusp addition—as worked out by Cope, Wortman, Schlosser, Scott, and myself. Rütimeyer's term, "trigonodont," best expresses the primitive structure of the upper and lower teeth, as of two interlocking triangles with their open bases turned outward in the upper and inward in the lower jaw. These "trigons" cutting past each other, made a shear so perfect that many Insectivora retained it without further evolution. But in most Trituberculates a talon was next added to the lower molar (Jurassic stage) as a pestle crushing into the upper valley; this talon gradually widened into a broad heel sup-

porting three cusps, as found in the Cretaceous. Consider the extreme antiquity of the three homologous cusps borne upon the back part of the human molar. This addition gave the opposed molars two shears and one crusher, and was so perfectly adapted to the needs of Lemurs and many Insectivores and Carnivores, in short, of most clawed animals, that they stopped at this point. Not so with the Herbivora, which required more extensive crushing surfaces. The upper molars, which had remained triangular through the Cretaceous and into the basal Eocene, began to develop a little talon, like that



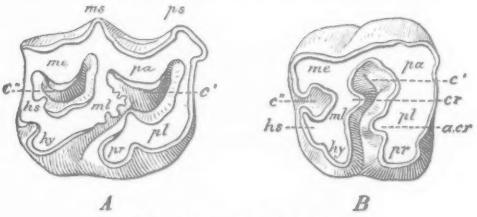
Phyletic History of the Cusps of the Ungulate Molars.
Upper molars in heavy lines, lower in light lines.

A, Reptilian Stage. Haplodont. Permian. *B*, Protodont Stage (*Dromotherium*), Triassic. *C*, Triconodont Stage (*Amphilestes*). *D*, Tritubercular Stage (*Spalacotherium*. *E* Tritubercular-tuberculo Sectorial (*Amphitherium*).* *F*, The same, in Upper Jurassic. *G*, The same, in Upper Cretaceous. *H*, The same, Puerco, Lower Eocene. *I*, Sexitubercular-sexitubercular, Puerco. *J*, Sexitubercular-quadritubercular, Wahsatch.

*Since this drawing was published I have learned that the talon of the lower molar of *Amphitherium* is considerably larger than here represented.

early seen in the lower molars, and at the same time both upper and lower molars entirely sacrificed their primitive cutting powers, and were converted from secodont into bunodont types by bringing the primitive trigons down to the level of the talons. At the same time, the upper molars acquired intermediate tubercles, and the triangular or oblique arrangement of the tubercles was shifted into the quadrangular or transverse arrangement. This outline is the result of fifteen years' observation.

With square crowns (*vs.* triangular) and six conic cusps above and below the molars of the Artiodactyl and Perissodactyl Herbivora ended their first constructive period and started upon their modernization. From this point we direct our attention upon the numerous combinations of three or four forms assumed by these single cones. The important thing now is to determine at what period these combinations were established, for there is wide difference of opinion as to when ungulate divergence began. To this I refer later. Taeker has recently shown how every modern embryonic lophodont or selenodont molar first exhibits the archetypal cones of the primitive bunodont. This law, together with my own parallel studies of the evolution of the horse and rhinoceros molars, led me to the discovery that these *embryonic primitive cones are also the main growth centers*, for, in the upper Miocene, long after the Perissodactyla have separated from each other, we see the influence of the archetypal form in the generic and specific variations of the molars. Compare the teeth of *Merychippus* and of *Aceratherium*, and imagine that you see underlying the diverse crests and crescents the simple bunodont molar of such a form as *Hyracotherium leporinum* of the London Clay. You will then notice that the characteristic secondary folds and spurs of the Miocene teeth spring from the old bunodont cones, that the two "cement lakes" of Merychippus are equivalent to the two "fossettes" of Acera-

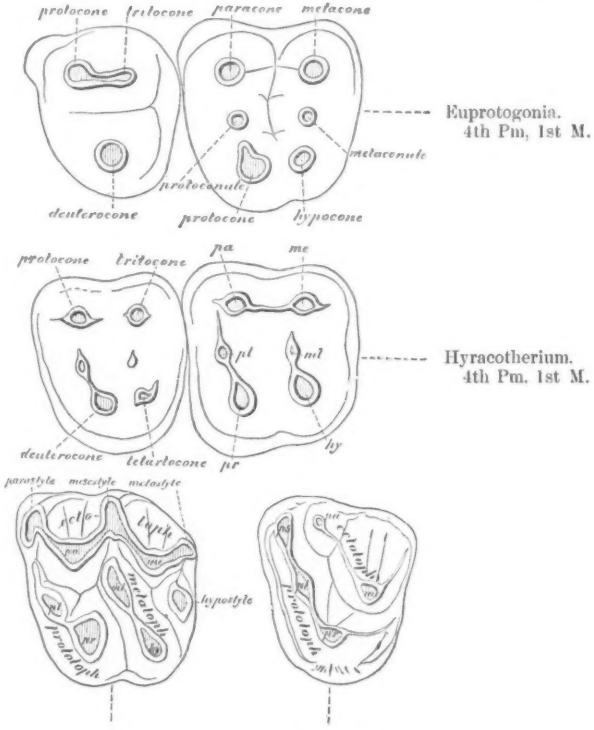


The Limits of Variation.

A, Merychippus. B, Aceratherium. Showing the secondary enamel foldings of the crests arising from the centers of the ancestral cones.

therium, because the "crescentic spurs" of the horse and the "crochet" and "antecrochet" of the rhinoceros spring alike from the primitive "intermediate tubercles."

In view of these discoveries of the uniformity of mammalian molar type, a uniform terminology has become as necessary for the dental cusps as for the carpal and tarsal elements of the feet. Professor Gaudry's once admirable system, elaborated in his "*Enchainements*," was based upon the supposed



Homologies in the Horse and Coryphodon Molars and Premolars.

division of the ungulate molar into a "first lobe" and "second lobe," and is still followed in France. Yet it has two drawbacks: it precludes the comparison of the ungulate with the unguiculate molar, for neither lobe includes the complete triangle; still more inconvenient is the fact that we cannot compare the higher ungulates with the older Coryphodons and Periptychidæ in which the molars were developed upon the

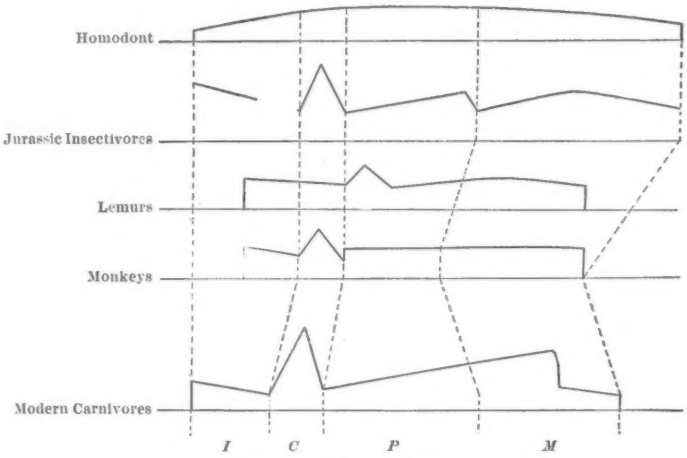
triangular plan; these teeth have only the first lobe and half the second. The upper molars of Hipparion and Coryphodon illustrate the advantages of this new system of comparison and of terminology.

Scott has made a further advance in Odontology by working out the laws of premolar evolution or cusp addition. In many groups we know that from one to four of the premolars gradually acquire the exact form of the molars in order to further increase the grinding surface, and we should *a priori* expect that the cusps would be added in the same order, and therefore be homologous with the molar cusps. This, as Schlosser and myself had observed, is not the case. Scott shows the order of cusp development in the premolars is very nearly the same in all the mammals, and yet is entirely different from the order followed in the molars. This law again unexpectedly ties the clawed and hoofed mammals together; the sequence of cusps in palingenesis is similar to that observed by Taeker in embryogenesis, and Scott is justified in proposing a new terminology (protocone, deuterocone, tritocone, etc.) for the premolar cusps, which will in the end prove to be a great convenience.

I alluded above to the well-known extreme and very confusing similarity of the tritubercular molars in the early stages of divergence. Trituberculism is at once the cause of clearness and of doubt when we get back to the stem mammals of widely different phyla. This has led to strange misconceptions of phyletic affinities as exemplified in Filhol's division "*Pachylémuriens*," a supposed mixture of lemur and ungulate stock. There was never any such mixture, and the question comes up how to distinguish unlike forms with like teeth? I have proposed to make use of a *dental curve* which will express the incipient atrophy of some parts, and hypertrophy of other parts of the series, a metatrophism which will naturally terminate in the reduction of some teeth, and excessive development of others. This has not been by any means fully worked out, but I believe it will prove to be of great service in directing attention to some of the initial tendencies of divergence, which are not expressed either in the dental formula or in the patterns of the teeth. Below are some of these curves. When worked out by the composite method, we will find certain primary curves characteristic of the ordinal divisions, and minor curves distinguishing the lesser divisions. Of course the laws of parallelism will also be found in force here; flesh-eating, insect-eating, and grass-eating animals will be apt to have similar curves even when evolved in different groups, but here the dental formula and succession will come to our aid.

Breaks and Links in the Mesozoic Fauna.

By our hypothesis all three sub-classes flourished together during the American Mesozoic; the Marsupials disappeared, then the Monotremes, and by the end of the basal Eocene the Placentals were in exclusive possession of the northern continent.



Examples of Dental Curves.

Although we have great reason to congratulate ourselves upon the rapid progress of discovery, there still remain great gaps in Mesozoic time between certain horizons and in the lineal phyletic series of both the Mesozoic and Cenozoic. For a time standard we may take advantage of the remarkably constant evolution of the Plagiaulacidæ in the Mesozoic, and of the Equidæ in the Cenozoic—as certain invertebrates are made use of in older rocks. The grooves and tubercles of Plagiaulax and the cusps and styles of the horses are added with the precision of clockwork, and supposing that the rate of evolution has been about the same, we can approximately estimate both the periods of deposition and the intervals as below.

PLAGIAULACIDAE.

	Stonesfield.	Purbeck.	Laramie.	Puerco.	Cernaysian.
Number of Premolars,	?	4–3	2	2–1	1
Grooves on Premolars.	?	7–9	11–14	12–15	14
Molar Tubercles: outer; inner;	?	4 : 2	6 : 4	6 : 4	9 : 6

Estimating the geological intervals by dental evolution and faunal succession, there is first the great gap between the Trias of Microlestes and Dromatherium and the Jurassic of the

Stonesfield slate; there is a relatively shorter interval, but still a considerable one between this and the Purbeck or Atlantosaurus beds. Then follows another long and very important interval between the Atlantosaurus beds and the Laramie (Upper Cretaceous). The gap between the Laramie and Puerco was relatively short as indicated by the comparatively limited evolution both of the Plagiaulacids and Tuberculates. The Puerco itself was a long period in which the Plagiaulacids underwent considerable changes. Then follows an interval which it is most important to fill by future exploration, for between the Puerco and the Wahsatch the differentiation of the even and the odd-toed ungulates must have occurred. The Wahsatch proper does not mark a very extensive evolution of the forms it contains. It passes after a slight break into the base of the Bridger (Wind River) and then begins that splendid and almost uninterrupted succession of lake basins, terminating in the Pliocene. I append a table, to be compared with that published by Marsh in his admirable address of 1877, and exhibit the great progress of the last sixteen years.

The general faunal succession is marked by the sudden appearance and disappearance of certain series and rise and fall of great groups. In the Trias appears the remarkable protodont or primitive-toothed Dromatherium; we cannot determine its Order at present. We still have no American fauna corresponding to the intermediate Stonesfield of England. In the Jurassic Atlantosaurus beds the three supposed representatives of the Monotremes (multituberculates), Marsupials (triconodonts) and Placentals (tuberculates), appear in equal numbers; the latter are generally characterized by the primitive dental formula. In the Laramie the Multituberculates continue in great profusion, and the Marsupials and Placentals are also numerous.

The serial succession of the Tuberculates from the Mesozoic is still an unknown chapter; we are utterly unable to connect the Dromatheriidæ of the Trias, the Triconodontidæ, Amphitheriidæ and Amblotheriidæ of the Jura with each other, or with any Cretaceous or lower tertiary mammals. The serial relations of the Multituberculates, on the other hand, have been made much clearer by the discovery of the Laramie fauna. Cope and Marsh in this country, and Smith Woodward in England, have at last broken into the long barren Cretaceous. In studying the accurate figures published by Marsh and a large collection of teeth recently made for the American Museum by Wortman and Peterson, I find that this Laramie fauna is widely separated from the Jurassic in its general evolution, and as Gaudry, Lemoine and Cope have observed, it approaches more nearly the basal Eocene of the Puerco and

THE SUCCESSION OF THE NORTH AMERICAN MAMMALIA.

PERIODS.	HORIZONS.	CHARACTERISTIC GENERA. NEW TYPES APPEARING.	TYPES BECOMING EXTINCT.
Post or Upper **PLIOCENE.**	EQUUS.	*Equus*, 5 species. Elephant. *E. primigenius*. Mastodon. Llamas. Camels, *Eschatius*, *Holomeniscus*. Elk, *Alces*. *Platygonus*. Sloths, *Mylodon*, *Glyptodon*. *Ursus*.	
TRUE PLIOCENE.	BLANCO.	*Equus*, 3 species. *Mastodon*, 3 sp. Llamas, *Pliauchenia*. *Platygonus*. Sloth, *Megalonyx*. *Felidæ* (?) *Hyænidæ*. *Mustelidæ*.	
MIOCENE.	LOUP FORK.	*Protohippus*, *Hipparion*. *Mastodon*. Rhinoceroses, *Aphelops*, 5 species. *Canidæ*. *Felidæ*. Rodents. Edentates. Camels and Llamas, *Procamelus*, *Protolabis*. Oreodons, 3 genera. Deer, *Blastomeryx*, *Cosoryx*.	Extinction of Oreodons and hornless rhinoceroses.
Upper.	DEEP RIVER.	*Protohippus*, *Anchitherium*. First Mastodons. Oreodons, *Cyclopidius*. *Chalicotherium*. Tylopoda.	Disappearance of Chalicotherium. Ext. of Creodonts, Hyænodons.
Middle.	JOHN DAY.	*Miohippus*. Two-horned Rhinoceros, *Diceratherium*. Peccaries. Oreodons. Rodents. *Canidæ*, *Felidæ*. Tylopoda.	Extinction of Elotheres and Hyopotamus.
Lower.	WHITE RIVER. PROTOCERAS. (Upper.)	(?) *Miohippus*. Artionyx. Appearance of tragulines, Elotheres, *Hyopotamus*, pigs and peccaries, true dogs, cats, monkeys. *Leptauchenia*. *Colodon*.	Extinction of Hyracodons.
	OREODON. (Middle.)	*Mesohippus*. Amynodon. *Chalicotherium*, *Aceratherium*, *Protapirus*, *Agriochœrus*, *Mesohippus*. Titanotherium. Opossums, Tylopoda, *Febrotherium*. Creodonts, *Hyænodon*. Rodents. Insectivores.	Extinction of Amynodons.
	TITANOTHERIUM. (Lower.)		Extinction of Titanotheres.
EOCENE.	UINTA.	*Epihippus*. *Amynodon*. Titanothere, *Diplacodon*. First Oreodons, *Protoreodon*. First Tylopoda, *Leptotragulus*. Tapirs. Hyracodons. Rodents. Creodonts, *Mesonyx*.	
Upper.	BRIDGER. WASHAKIE. (Upper.)	*Pachynolophus*. Appearance of Amynodons and horned Titanotheres. *Palæosyops*. *Hyrachyus*. *Triplopus*. *Achænodon*.	Extinction of Dinocerata, of some Creodonts.
	BRIDGER. (Middle)	*Pachynolophus*. Appearance of Insectivora, Cheiroptera, Hyracodons, *Uintatherium*. *Palæosyops*. Creodonts.	Extinction of Tillodontia.
Middle.	WIND RIVER. (Lower.)	*Hyracotherium*. *Palæosyops*. Dinocerata. *Coryphodon*. *Phenacodus*.	Extinction of Coryphodontia and Condylartha.
	WAHSATCH.	*Hyracotherium*. Appearance of Artiodactyls, Perissodactyls; tapirs, horses, titanotheres, lophiodons. First Rodents. First Coryphodons. Lemurs and Monkeys. Creodonts, 6 families, *Palæonictis*.	Extinction of Arctocyons.
Lower.	Interval.	(*Differentiation of modern clawed and hoofed placentals.*)	
	PUERCO.	*Ptilodus*. *Neoplagiaulax*, *Polymastodon*. Ancient types of Ungulates, Carnivores and Insectivores: Amblypoda, Condylarthra, Creodonta. Tæniodonta. Tillodontia. Lemurs.	Extinction of Multituberculates, (? Monotremes).
	Interval.	(*Differentiation of ancient clawed and hoofed placentals.*)	Disappearance of Marsupials.
UPPER CRETACEOUS.	LARAMIE.	*Ptilodus*. *Bolodontidæ* (Multituberculates). *Thlæodon*. Tuberculate Placentals and Marsupials, typical dentition.	
	Interval.		
MIDDLE JURASSIC.	Atlantosaurus.	*Ctenacodon*. *Plagiaulax*, *Bolodon*. Multituberculates (? Monotremes). Triconodonts (? Marsupials). Tuberculates (? Placentals), primitive dentition.	
	Interval.		
UPPER TRIASSIC.	Chatham Coal Beds.	*Protodonta*, *Dromotherium*, *Microconodon*, primitive Triconodonts (? Monotremes).	

the Cernaysian of France. The Multituberculates of the Laramie include the Plagiaulacidæ, represented by Ptilodus, the form with two premolars, and Meniscoëssus, with two premolars and crescentic tubercles Meniscoëssus has a smaller fourth premolar, and is found to lead off to the huge plagiaulacid Polymastodon of the Puerco. The only other Multituberculates found are those related to Bolodon of the Jurassic and Chirox of the Puerco. The other mammals of the Laramie range from the mouse to the opossum in size; they have superior molars of the simple tritubercular type—the low cusped or bunodont molar predominating in the upper jaw, and the tuberculo-sectorial in the lower. The dental formula is mostly the typical p. 4, m. 3. Yet, judging by the angular region of the jaws, we have here both Placentals and Marsupials. Some of the teeth remind us strongly of those in the Puerco; their determination, however, is very difficult, for the jaws and teeth are almost entirely isolated. From another exposure of the Laramie, Cope has recently found the remarkable type Thlaeodon—remarkable because it is a highly specialized tritubercular of typical dentition with a jaw which bears resemblance to that of the Multituberculates and of Ornithorhynchus. There is no placental angle nor strong marsupial inflection. This raises the supposition that Thlæodon may be one of the persistent tritubercular Monotremes which we are now looking for.

In the Puerco or basal Eocene, a very marked change occurs, for the American fauna loses some of its cosmopolitan character, the Multituberculates or monotremes die out and the marsupials are not found at all; in fact they do not reappear in North America until the Miocene.

Ancient and Modern Placental Differentiation.

The Puerco is essentially an archaic fauna and is to be regarded as the climax of the first period of placental differentiation, a culmination of the first attempts of nature to establish insectivorous, carnivorous and herbivorous groups. These attempts began in the Cretaceous, and some of the types thus produced died out in the Puerco, some in the Wahsatch and Bridger; only a few flesh-eaters survived to the Miocene. It is most important to grasp clearly the idea of this functional radiation in all directions of this old Puerco fauna, resulting in forms like the modern insectivores, rodents, bears, dogs and cats, monkeys, sloths, bunodont and selenodont ungulates, and lophodont ungulates. This was an independent radiation of placentals, like the Australian radiation of marsupials. What

was the cause of the wide-spread extinction of these types? So far as the ancient clawed types are concerned, their teeth and feet seem to be as fully adaptive in many cases as those of the later unguiculates; the hoofed types were certainly inferior in tooth evolution, for all their molars evolved on the triangular basis instead of the sexitubercular; the most sweeping defect of both the clawed and hoofed types, was the apparent incapacity for brain growth, their bodies went on developing while their brains stood still. Thus the stupid giant fauna, the Dinocerata, which rose out of this period, gave way to the small but large-brained modern types. It is noteworthy that the latest survivors of this wreck of ancient life were the large-brained Hyænodons.

Some of the least specialized spurs of this radiation appear to have survived and become the centers of the second or mid-Tertiary radiation from which our modern fauna has evolved. Yet we have not in a single case succeeded in tracing the direct connection. To sum up, we find on the North American continent evidence of the rise and decline and disappearance of monotremes and marsupials, and two great periods of placental radiation, the *ancient radiation* beginning in the Mesozoic, reaching a climax in the Puerco and unknown post-Puerco, and sending its spurs into the higher Tertiary, and the *modern radiation* reaching its climax in the Miocene, and sending down to us our existing types.

Another Eocene center was lower South America, which has of late dimmed the prestige of North America in yielding strange forms of life. One theory of this Patagonian fauna is that it was an independent center of functional radiation like the Puerco and Australian, full of adaptive parallels, but not yielding to Europe or America any of their older types. But Ameghino, to whose energetic researches we are chiefly indebted, believes that he finds a lower Eocene life zone—a sort of *south polar* center—which supplied both America and Europe. The Puerco he believes is no older than the Santacruzian which in turn is very much older than the Parana and Pampean formations, which Burmeister has made so well known. This yields the Homunculus patagonicus which parallels Cope's Anaptomorphus in presenting a dentition as advanced in reduction as that of man. Ameghino finds here the ancestors of the Macrauchenidæ; he believes the Homolodontotheridæ are the ancestors of the Chalicotheriidæ—thus mistakenly deriving a buno-selenodont from a lophodont type; the Proterotheriidæ, he believes, replace the Condylarthra and

Hyracotherium in the ancestry of the horses. Similarly the Microbiotheriidæ are the stem of the creodonts and carnivores. I cannot coincide with any of these views. The Multituberculates are far older and widely different from the Abderites to which Ameghino traces their ancestry. I fully concur with the opinion of Cope, Zittel, Scott and others that this fauna is of somewhat later age, that it was directly connected with Australia and somewhat later with North America, supplying us, as has always been supposed, with our sloths. I quote from a recent address by Scott:

"The oldest mammals from South America are those from Patagonia, which Ameghino has referred to the Eocene, but which are more probably Oligocene or Miocene. This fauna is of extreme peculiarity and isolation; it is made up chiefly of edentates, rodents and ungulates of those very aberrant types known as Litopterna and Toxodontia, which are so widely different from the hoofed mammals of the northern hemisphere; together with some primitive forms of primates, creodonts and marsupials. The marsupials are of extraordinary interest, for they comprise not only forms allied to the opossums, but also to recent Australian forms such as Thylacinus, Dasyurus and Hypsiprymnus. This is a most unexpected fact and seems to point unmistakably to a great southern circumpolar continent."

The North American Puerco thus remains the most extensively known and productive lower Eocene center yet we have very slender threads of positive evidence to connect its fauna with the later placental radiation.

The Creodonts of Cope occupy the same relation to the modern insectivores and carnivores that the Condylarthra do to the ungulates. The American group has been recently enriched by the discoveries of Wortman, and the literature by the careful revision of Scott. This author has divided them into eight families, placing the forms which most resemble the Insectivora in the new family, Oxyclænidæ. These families illustrate superbly the same law of functional radiation later repeated in the placental and marsupial carnivores. The Mesonyx family presents some analogies to the Thylacines. The modern bears are paralleled in the Arctocyons, with their low tubercular molars; Wortman and myself, with fresh materials, have recently added Anacodon to this family, a genus which was doubtfully regarded by Cope as an ancient ungulate. The Cats and Hyænas are imitated in the Oxyænas and Hyænodons, some of the Miocene forms of which Scott suggests developed aquatic habits; as above noted, some of this family acquired large brains and persisted well into the Miocene. A

still more remarkable likeness to the Cats is exhibited in the Palæonictis family, which, unlike the Hyænodons, forms its sectorials out of exactly the same teeth as the true cats. The first American Palæonictis was found two years ago by Wortman, and this author and myself have suggested that this may be the long-sought ancestor of the Felidæ. The Civets are anticipated in the Proviverridæ; yet both Cope and Scott, the highest authorities on this subject, believe that the dog-like Miacidæ alone formed the connecting link between the Creodonta and the true Carnivora.

The foot structure of the ancient Puerco ungulates is still only partly known. Cope has divided these animals into the Amblypoda and Condylarthra. The Amblypoda are represented in the Puerco by a large form called Pantolambda, with selenodont triangular upper molars, and possibly by Periptychus, with bunodont triangular molars. The Pantolambda molars were, as Cope has shown, converted into those of Coryphodon, the great lophodont Amblypod of the Wahsatch, by a process exactly analogous to that in which the *anterior* half of a Palæotherium molar was formed, that is, they acquired outer and anterior crests but no posterior crests. This Coryphodon molar type was still later converted into the Uintatherium type by swinging around the outer crest into a transverse crest. I have recently made a careful study of the fore and hind feet of Coryphodon, and have found that while the fore foot was subdigitigrade like that of the elephant, the hind foot was fully plantigrade, the entire sole resting upon the ground. The relation or connection between the Bridger Dinocerata and these earlier Amblypoda is still unknown. The Puerco Periptychus left no descendants. The other ungulates of the Puerco were the Condylarthra, including the primitive Phenacodontidæ, the supposed ancestors of the Artiodactyls and Perissodactyls. Much remains to be done to clear up their relationships.

Succession of the Perissodactyls.

In the Wahsatch and Wind River we find not only the last of the Phenacodonts and Coryphodonts and the first of the Dinocerata, but the first of the true Artiodactyls and Perissodactyls. Recent studies of Cope, Schlosser, Pavlow, Filhol have been directed to the phylogeny of the Perissodactyls with very different conclusions. I agree most closely with Schlosser, and have endeavored to show that the molar teeth give us a key to their natural arrangement as shown in this column.

. . . { Titanotheres.
. . . { Horses. Palæotheres.
. . . { Tapirs. Lophiodonts. (Helaletes).
. . . . { Hyracodonts. Amynodonts. Rhinoceroses.

Upon one side the Titanotheres present the buno-selenodont extreme with most analogies to the Artiodactyla in tooth structure and in their truly Artiodactyl fore feet and bony horns. (If, as Cope supposes, the Diplarthra form a natural group, some Perissodactyls should certainly be more Artiodactyl than others.) The Horses and Palæotheres diverge from the buno-selenodont type towards the Lophodont; they were early separated in foot structure. The Tapirs, Lophiodonts, and Helaletes show well-marked transverse crests and incipient external crests. This brings us to the other Lophodont extreme, the Rhinoceros-like forms, with complete transverse and external crests. There are many other minor characters which support this as the natural arrangement of the Perissodactyls. I think it can be shown conclusively that these eight or nine series diverged from each other before the Wahsatch, and that all attempts to derive them from each other in later periods will break down. They will be found to converge into the unknown Sub-Wahsatch period, to stem forms as indicated by the brackets.

* * * * * * * * * *

The Titanotheres have been traced by Cope back to Lambdotherium in the Wahsatch; in the Wind River the true Palæosyops is found, and in the Bridger this becomes the predominant perissodactyl family, and spreads out into a great variety of forms, which have recently been carefully described by Earle. In the Washakie there are some still larger forms, and Marsh has traced the line through the teeth of Diplacodon of the Uinta to the true Titanotheres. Still the origin of the flattened skull and remarkable anterior pair of horns has never been known; Hatcher reports species with very small horns in the base of the Titanotherium beds (Lower Miocene). Wortman has just reported to me the brilliant discovery of an upper Eocene (Bridger and Washakie) Palæosyops with a flattened skull and rudimentary horns just appearing upon the nasals! This forms the desired connecting link.

The early history of the horses, probably starting with the Puerco Condylarth Euprotogonia, and passing through Hyracotherium, Pachynolophus, Epihippus, Mesohippus, is now familiar enough. It is the later history which requires elucidation, and is producing the most unexpected number of parallel lines of horses, out of one of which only our modern horse sprang. Here we are especially indebted to Cope, Pavlow, and Scott. By general consent Hipparion comes out of its old position in the true line as displaying the most extreme

variations in the crowns of the molar teeth in compensation for the backward evolution of its feet. Scott has been especially investigating the upper Miocene horses; I quote from the MSS. he has kindly lent me, in which he proposes to remove also the classical Anchitherium of Cuvier. He says: "These American genera, Mesohippus and Miohippus may confidently be regarded as important members of the equine stem, while Anchitherium (of Europe) from present information would appear to belong to an abortive side branch leading to no permanent results." Scott has also discovered an important intermediate form linking Miohippus with Protohippus.

The Palæotheres have not been found in America.

The Tapir line has been traced by Cope and myself back to Systemodon of the Wahsatch, and Isectolophus of the Bridger and Uinta. These forms have simple premolars, but bear the most striking resemblance to the Tapirs in the molars both above and below. All previous attempts to determine the Miocene representatives of the Tapirs have been erroneous. Wortman and Earle have just published an account of two lower Miocene species of true Tapirs, which, both in foot and tooth structure, definitely carry the American Tapir line up to the middle Miocene, where it is again lost sight of. These species belong to the genus Protapirus, which Filhol has found in the Oligocene of France, thus adding an important geological parallel. The Wahsatch Tapirs were a little larger than the Horses or Hyracotheres which were about the size of a fox, and much smaller than the ancestral Titanotheres.

Another family of small, slender perissodactyls more nearly allied to the Lophiodons of Europe than any other American forms are the Helaletidæ, distinguished by feet tending to monodactylism, and narrow hoofs like those of the deer; even in the Wahsatch Heptodon the lateral toes are quite short and raised off the ground. The molars, like those of the lophiodons of Europe, are intermediate between those of the Tapir and the Rhinoceros, but both teeth and feet preclude our uniting these forms either with the Tapirs or with the Hyrachyus family, as Cope has done. The Bridger successor is Helaletes, which Marsh mistakenly supposed was an ancestral Tapir, and the integrity of this line is now firmly established by the discovery of the Miocene Colodon. This is described by Marsh as a successor of Helaletes, and Wortman and Earle have just published an account of the teeth and feet, showing that Colodon is widely separated from the contemporary true Tapirs, and is the last member of the Heptodon-Helaletes line.

The Rhinoceroses of America comprised the true Aceratheriinæ and Diceratheriinæ, and what may be called the

pseudo-rhinoceroses, the Hyracodons and Amynodons; all these forms present the true Rhinoceros molar pattern, but they diverge most widely in the structure of the anterior teeth and of the feet. The Hyracodons first appear in the numerous and diversified Hyrachyus of the Bridger, some of which exhibited rudimentary horns upon the back part of the nasals (Colonoceras); they retained a full set of equal-sized incisors and canines, and acquired a horse type of skull, skeleton, and locomotion. Scott has well named them the "cursorial rhinoceroses." Colonoceras probably did not, as Marsh has suggested, branch off into Diceratherium, for the horns of this true rhinoceros are developed at the ends of the nasals; the Hyrachyinæ sent off as a side branch the deer-like Triplopus of the Washakie, and terminated in the Hyracodons of the lower Miocene.

The Amynodons, at the time of their discovery by Marsh, were naturally supposed to be the long-sought Eocene rhinoceroses, but I have shown that no Amynodon can fill this rôle. Garman's discovery of the skull of the remarkable Miocene Metamynodon tended to confirm my views, and I have now to report the discovery of many skulls and a nearly complete skeleton by the American Museum Expedition. This proves that the Amynodontidæ were remarkable side forms. In wide contrast with the true rhinoceroses, the upper and lower canines develop into huge, partly recurved tusks, like those of the boar. As in Elasmotherium, the premolars become greatly reduced, and the molars tend to hypsodontism. The lower molars are long and narrow, like those of the anomalous Cadurcotherium of the Oligocene of Europe—it is thus rendered probable that Cadurcotherium is not a sloth, as Filhol has suggested, but is an aberrant rhinoceros, related to, if not identical with, the Amynodons. The hypsodontism in some Metamynodon teeth is accompanied by a partial loss of enamel. To complete the aberrant character of this family, we find that it has four equal-sized and completely functional toes in the forefoot, like those of the Titanotheres, not with the fifth toe reduced as in the contemporary Aceratheria.

The true Rhinoceroses, we remember, are distinguished by the entire loss of upper canines. Wortman has just reported finding rudimentary upper canines in both the milk and permanent dentitions of the older Miocene species. The true rhinoceroses suddenly appear in the lower Miocene of America and Oligocene of Europe; we have not yet traced them back. In a collection of lower Miocene skulls recently obtained for the American Museum we find that the premolars are still very simple. In the higher Oreodon beds all traces of the superior canine are lost, and the premolars have become more like the

molars. As the origin of the rhinoceroses still remains a mystery, so their later evolution needs clearing up. The American series suddenly terminate in the huge, hornless forms of the upper Miocene. I find there is still no unanimity of opinion as to the phyletic relationships of the Miocene, Pliocene and existing species of Europe.

Succession of the Artiodactyls.

The Eocene Artiodactyl phylogeny is still far behind that of the perissodactyls, but the Miocene and Pliocene succession has been worked up with great success and clearness by Cope and Scott. The latter says in a recent paper: "All the great groups of Artiodactyla are seen to arise independently from the Buno-Selenodonta which forms as it were a lake, from which several streams, flowing partly in parallel partly in divergent directions, are derived."

The Elotheriidæ appear in Parahyus of the Bridger and Achænodon of the Washakie, and terminate in the middle Miocene in the gigantic *Elotherium ramosum*, an animal with a skull three feet long, both the jaws and skull being armed with long branching processes. The true bunodont pigs and peccaries have not yet been found lower than the White River.

Scott has traced the Oreodons back to Protoreodon of the top of the Eocene. The aberrant Agriochœridæ, he believes, were doubtfully connected with the true Oreodons by a lower Eocene stem form. The true Oreodons, which existed in great herds in the lower Miocene, have been divided by Cope and Scott into three parallel lines extending into the Loup Fork, namely, the large Merycochœrus, the medium-sized Merychyus and the small, highly-specialized Pithecistes.

The Tragulines are represented by Leptomeryx, Hypertragulus and Hypisodus. Leptomeryx is believed to be a side member of the main family.

Here I may speak of the recent discovery of the characters of the Protoceratidæ, a new family with a remarkable ensemble of characters. In 1891 Marsh described the female skull of Protoceras with a small pair of parietal protuberances. The male skull was found by the American Museum party of 1892. It is armed not only by upper canine tusks, but by four pairs of cranial protuberances, two of which might be dignified by the name of osseous horns; it thus presents the armature of an Uintatherium upon a small scale. Besides parietal and two pairs of frontal protuberances, there are a pair of most exceptional maxillary plates. The fore foot is like that of Tragulus, while the hind foot is didactyl like the deer. We can at present form no idea of its affinities.

The oldest American Artiodactyl certainly known is the tritubercular Pantolestes of the Wahsatch. Cope believes the line of American Llamas may have sprung from this, and have been continued through Homacodon of the Bridger. The first undoubted cameloid is Leptotragulus of the Uinta, a comparatively recent discovery. It has strikingly reduced feet for such an early form. Pœbrotherium of the White River and John Day has quite the proportions of the living llama; thence the line passes into Protolabis of the Deep River and John Day. Scott believes that these forms are undoubtedly related to both the camels and llamas, and that in the Loup Fork, perhaps in the two species of Procamelus, the division occurs, *P. angustidens* passing into the camels, and *P. occidentalis* into the llamas. The Pliocene Homocamelus, Holomeniscus and Eschatius, Scott believes may represent a highly specialized side line of camels; while Pliauchenia, still imperfectly known, may belong on the llama side.

The deer represented by Cosoryx and Blastomeryx are, so far as we know, not of American origin, for they first appear in the Upper Miocene at Loup Fork.

The Ancylopoda.

The order Ancylopoda Cope presents the most signal exception to the law of correlation. It is only quite recently that Filhol, Forsyth Major and Depéret have brought together the sloth like phalanges with the ungulate type of teeth of the Chalicotheriidæ. Since 1825, when Cuvier described the phalanges from Eppelsheim as those of a "*pangolin gigantesque*," referring to their deep clefts, and 1833, when Kaup named the teeth, these structures were always considered distinct. It is probable that Moropus and other supposed Sloths described by Marsh from our Miocene also belong in this exceptional order. As now restored by Filhol and myself, this remarkable Chalicotherium had a gait less clumsy than the Sloth, and something between a huge cat and a hoofed animal; it combined the skull of a primitive ungulate with the molars of an eocene titanothere, for the premolars are simple. The limbs, wrist and ankle bones are chiefly ungulate and perissodactyl. In viewing this combination of characters, the first question to settle is which set of characters is secondary and adaptive. I agree with Depéret, as against Filhol who regards this as an aberrant edentate, that the unguiculate characters are secondary; but I do not believe it is very near the Perissodactyla. It seems to have sprung rather from the primitive ungulate stem before it had parted with its unguiculate characters. Perhaps it came off from the Wahsatch

Meniscotherium, a member of the Condylarthra, which it very closely resembles in its skull and molar structure and in its dental curve. Marsh, by the way, has just added to our knowledge of this little Wahsatch genus by describing its fore and hind feet, which are more primitive than those of Phenacodus or Hyrax. While the Creodonta were imitating all modern carnivores, is it not posssible that the Condylarthra gave off a sloth-like form for fossorial and semi-arboreal habits?

Last summer while this problem was being discussed, we were brought face to face with the exact counterpart of Chalicotherium which may be called a *clawed odd-toed* form, by the surprising discovery of a hind foot, which represents a *clawed even-toed* animal. This was found by the American Museum party in the Protoceras beds of South Dakota, and has been named Artionyx. This foot has a truly Artiodactyl tarsus and metatarsus like that of the pigs or oreodons. Yet it possesses five toes terminating in large uncleft claws. It has been suggested by Wortman and myself that it represents an Artionychine (even-clawed) division and that Chalicotherium represents a Perissonychine (odd-clawed) division of the Ancylopoda; in other words, that a double parallelism exists with the Ungulata. Another explanation may be that these genera are highly specialized Artiodactyla and Perissodactyla respectively; Scott has made the ingenious suggestion, tending to support this theory, that the Artionyx foot is the long unknown foot of the aberrant orèodont Agriochœrus of Leidy. This summer will probably determine the truth of this suggestion, for two parties are hunting in the beds in which Agriochœrus and Artionyx occur.

Thus an immense number of problems still await solution, and demand the generous coöperation of European and American specialists in the use of similar methods of research, in the prompt publication of descriptions and figures, and in the free use of museum collections. I may be pardoned for calling general attention to the service which the palæontological department of the American Museum is trying to render in the immediate publication of stratigraphical and descriptive tables of western horizons and localities.

The Factors of Evolution.

A few words in conclusion upon the impressions which a study of the rise of the mammalia gives as to the factors of organic evolution. I refer also to recent papers by Cope, Scott and myself.

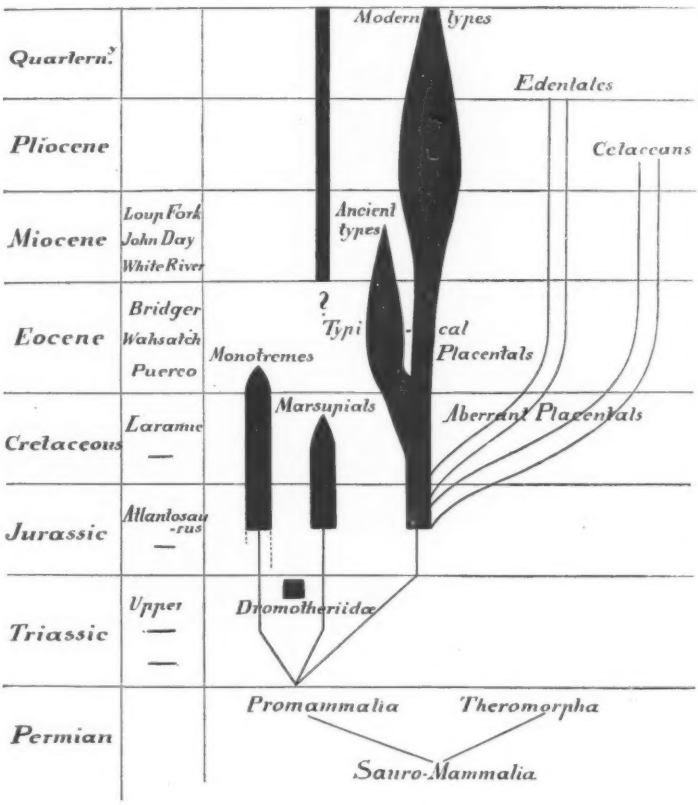
The evolution of a family like the Titanotheres presents an uninterrupted march in one direction. While apparently

prosperous and attaining a great size, it was really passing into a great corral of inadaptation to the grasses which were introduced in the middle Miocene. So with other families and lesser lines, extinction came in at the end of a term of development and high specialization. With other families no causes for extinction can be assigned, as in the lopping off of the smaller Miocene perissodactyls. The point is that a certain trend of development is taken leading to an adaptive or inadaptive final issue—but extinction or survival of the fittest seems to exert little influence *en route*.

The changes *en route* lead us to believe either in predestination—a kind of internal perfecting tendency, or in kinetogenesis. For the trend of evolution is not the happy resultant of many trials, but is heralded in structures of the same form all the world over and in age after age, by similar minute changes advancing irresistibly from inutility to utility. It is an absolutely definite and lawful progression. The infinite number of contemporary developing degenerating and stationary characters preclude the possibility of fortuity. There is some law introducing and regulating each of these variations, as in the variations of individual growth.

The limits of variation seem to lie partly in what I have called the "potential of evolution." As the oösperm or fertilized ovum is the potential adult, so the Eocene molar is the potential Miocene molar. We have seen that the variations of the horse and rhinoceros molars, apparently so diverse, are really uniform,—is not this evidence that the stem perissodactyl had these variations *in potential*, waiting to be called forth by certain stimuli? This capacity of similar development under similar stimuli is part of the law of mammalian evolution, but this does not decide the crucial point whether the stimulus is spontaneous in the germ or inherited from the parent. I incline to the latter opinion.

Columbia College, August 3, 1893.



Hypothetical Phylogeny of the North American Mammalia.

The Monotremes disappear in the basal Eocene. The Marsupials disappear in the upper Cretaceous and reappear in the lower Miocene, (*Didelphys*). The aberrant Placentals branch off in the upper Jurassic. The typical Placentals divide into the "Ancient types" dying out in the Miocene, and the "Modern types" still existing. The aberrant Placentals are given off in mid-Mesozoic times.

Art. LXII.—*On the Thoracic Legs of Triarthrus;* by C. E. Beecher.*

The first conclusive evidence of the presence of legs and gills in the *Trilobita* was given in 1876 by C. D. Walcott,† who by means of translucent sections was enabled to demonstrate their existence in four genera, and to indicate several important points in their structure. The genera shown to possess legs were *Ceraurus*, *Calymene*, *Asaphus*, and *Acidaspis*. Various announcements of the discovery of the legs of trilobites had been made previously, but, with the exception of a specimen described by Billings in 1870, these proved to be erroneous determinations. Walcott has since made further studies, and brought together his conclusions in a paper published in 1881.‡ Until 1893, no additions of note have been made beyond those confirming the fact that these animals possessed jointed legs. The specimens investigated by Walcott consisted chiefly of coiled individuals in which the body cavity was filled with calcite and clayey matter. There was no actual mineralization of the appendages, but the fillings of the cavities left by the decay of these organs served to show their general form. On account of their enrolled condition, considerable difficulty was experienced, and there was also a liability to error in attempting to determine the precise characters of the organs observed. Notwithstanding these drawbacks, some of the main points in the ventral anatomy of these animals were established.

The occurrence of *Triarthrus Becki* Green, in an exceptionally perfect state of preservation, from the Utica Slate near Rome, N. Y., has already been noticed in this Journal.§ In their present condition, the specimens contain very little calcareous matter, and nearly the entire calcareous and chitinous portions of the animal are represented by a thin film of iron pyrite. To this kind of fossilization is doubtless due the preservation of delicate organs and structures which otherwise would have been destroyed. For, as is well known, pyrite may replace such organic tissues as chitine or even soft dermal structures, the change occurring by the slow decomposition of

* Abstract of a paper "On the Structure and Development of Trilobites" read before the National Academy of Sciences, November 8, 1893.

† Preliminary Notice of the Discovery of the remains of natatory and branchial appendages of Trilobites. 28th Ann. Rept. N. Y. State Museum of Natural History, published in advance. December, 1876.

‡ The Trilobite: new and old evidence relating to its organization. Bulletin of the Museum of Comparative Zoology, vol. viii, No. 10, 1881.

§ Vol. xlvi, pp. 121–125, 378–379, August and November, 1893.

these tissues in the presence of iron sulphate in solution, or from the action of hydrogen sulphide as a result of decomposition in a chalybeate water.

It was apparent that specimens preserving organs so delicate as antennæ ought to show in addition other anatomical features of great interest. This expectation has been fully realized in the study and preparation of the collection belonging to the Yale University Museum, but at present it is proposed to give only a preliminary description, and to figure some of the details of the thoracic legs.

No essential differences have been observed in the series of legs attached to the segments of the thorax. Each segment bears a pair of biramous appendages originating at the sides of the axis (Walcott). The anterior legs are the longest and the others gradually become shorter towards the pygidium. Those which are here taken for description are the legs of the second and third free thoracic segments. The entire length of the legs has been exposed, from the dorsal side, by removing the overlying pleuræ of the thorax which concealed nearly half their length. Each limb consists of two nearly equal members, one of which was evidently used for crawling and the other for swimming. These two members and their joints may be correlated with certain typical forms of Crustacean legs among the *Schizopoda*, *Cumacea*, and *Decapoda*, and may be described in the same terms. Therefore, each limb is composed of a stem, or shaft, with an outer branch (exopodite), and an inner branch (endopodite). Figure 3 shows the joints of the stem (6, 7), the exopodite (*ex*, 1 and 2), and the endopodite (*en*, 1–5). The precise details of the coxal joint of the stem (coxopodite) have not yet clearly been made out. It is followed by a broad joint about twice as long as wide, which may be referred to the protopodite.

The endopodite was the member used for crawling, as in the *Schizopoda*. The three proximal joints, the ischiopodite (5), meropodite (4), and carpopodite (3), are similar in form to the protopodite (6), and taper gradually outwards. The distal portion is completed by two shorter cylindrical joints, the propodite (2) and the dactylopodite (1), the latter bearing at its extremity short setæ, or bristles, of which three are commonly to be seen.

The other member, the exopodite, lies over the endopodite. It apparently articulates with the protopodite, but may spring from what is here referred to the coxopodite, as its basal portion is very broad and originates close to the articulation of protopodite with the coxal joint. The proximal joint of the exopodite (2) is somewhat arched and tapers rapidly. It extends to the ends of the pleuræ, and is the longest joint of

either branch. The posterior edge is finely denticulate, and carries a row of long setæ. The distal portion (1) is multiarticulate, being composed of ten or more joints. In general form, it is slightly crescentic, with the margins thickened, the anterior one being strongly crenulated. Long setæ extend posteriorly from the crenulations on the dorsal side of the leg, making a conspicuous fringe along the distal half of the exopodite.

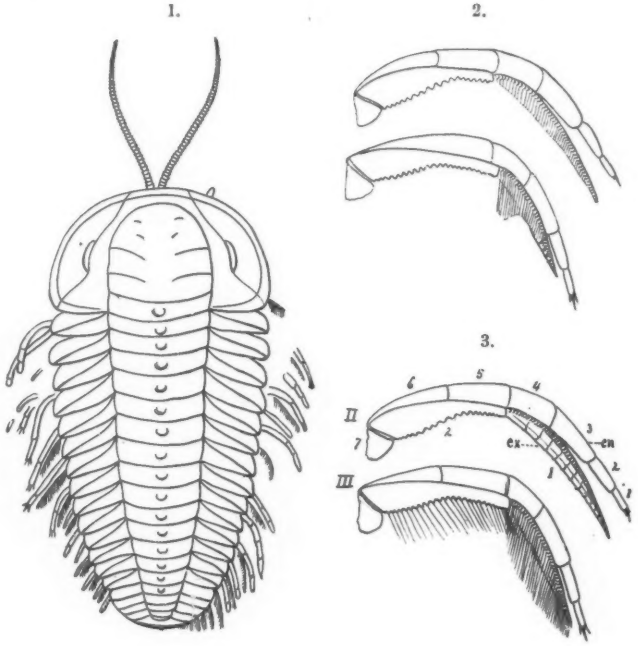


FIGURE 1.—*Triarthrus Becki* Green; dorsal view; showing antennæ and paired crawling and swimming thoracic legs ×3. (The antennæ and legs on right side are from one specimen ×3, and the legs of the right side are drawn from a smaller individual ×6).

FIGURE 2.—*Triarthrus Becki* Green; dorsal view of right legs of second and third free thoracic segments. ×12.

FIGURE 3.—The same, with setæ omitted from II, to show details of structure *ex*, exopodite; *en*, endopodite. The setæ are represented on III. ×12.

Figure 1 represents a dorsal view of *Triarthrus Becki*, showing the antennæ and the exposed portions of the appendages. The antennæ and legs on the right side are drawn from one specimen, and the legs on the left side are as shown in

another individual. The biramous character of the entire series of thoracic legs is very evident, as is also the distinction between the crawling and swimming members. Figure 2 shows the right second and third legs of the free thoracic segments. In figure 3, the upper exopodite is represented without setæ, so as to bring out the structure in greater detail. On the lower leg the setæ are shown.

It is not proposed at this time to make any extensive comparisons or homologies with other groups of Crustacea, as the appendages of the head and pygidium still require further description and illustration, and will be the subject of a future contribution. It is evident, however, that the relations of the trilobites are with the *Entomostraca* and *Malacostraca*. Moreover, like the *Leptostraca* (*Nebalia*), the *Trilobita* probably constitute an intermediate type having affinities with the *Entomostraca* chiefly in the irregular segmentation, and with the lower forms of the *Malacostraca* (as the *Schizopoda*, *Cumacea*, and *Anisopoda*) in the detailed structure of the limbs.

ART. LXIII.—*On the Diamond in the Cañon Diablo Meteoric Iron and on the hardness of Carborundum;* by GEORGE FREDERICK KUNZ and OLIVER W. HUNTINGTON, Ph.D.

THE discovery of diamonds in the Cañon Diablo meteoric iron was first announced by Dr. A. E. Foote in this Journal for July, 1891 (vol. xlii, pp. 413–417). He found in the cutting of this meteorite that it was of extraordinary hardness, a day and a half of time being consumed and chisels destroyed in the process of removing a section. In cutting, the chisels had fortunately gone through a crevice filled with small cavities. The emery wheel used to polish this surface was ruined, and on examination the exposed cavities were found to contain hard particles which cut through polished corundum as easily as a knife cuts gypsum. The grains exposed were small and black, and Professor Geo. A. Koenig pronounced them diamonds because of their hardness and indifference to chemical agents. The extreme hardness was subsequently verified by one of us (G. F. Kunz), who carefully examined the type specimen.

On July 8, 1892 (Science, p. 15), Dr. Oliver Whipple Huntington gave the result of his experiments with this remarkably interesting Cañon Diablo iron. Taking one hundred grams of the iron he placed it in a perforated platinum cone suspended in a platinum bowl filled with acid, the cone

being made the positive pole and the dish the negative pole of a Bunsen cell. The iron was slowly dissolved, leaving on the cone a large amount of black slime. This was carefully collected, digested over a steam bath for many hours, first with aqua regia, and afterwards strong hydrofluoric acid. A considerable part of the residue disappeared, but there remained a small amount of white grains which resisted the action of the acids. These particles, when carefully separated by hand, had the appearance of fine beach sand. Under the microscope they were found to be transparent and of brilliant luster. One of the grains was then mounted upon a point of metallic lead, which, when drawn across a watch crystal, was found to give the familiar singing noise characteristic of a glass cutter's tool and with the same result, namely, cutting the glass completely through. It deeply cut glass, topaz, and a polished sapphire. These facts, first announced in Science, April 8, 1892, were presented at the meeting of the American Academy of Arts and Sciences on May 11, 1892, and were published in the Proceedings of this Academy, new series vol. xxii, pages 252–253.

Later M. C. Friedel says in the Bulletin de la Société Francaise de Mineralogie,* that he took a fragment of the Cañon Diablo meteorite weighing 34 grams, which gave the characteristic Widmannstattian figures, and treated it with hydrochloric acid. He digested the residue in aqua regia and obtained a black powder. After various treatments he thus separated about ·35 gram of a powder which he presented to the Academy. The powder sank in a solution of the iodide of methyl having a density of 3·3. No grains measuring more than $\cdot 5^{mm}$ to $\cdot 8^{mm}$ were found, the powder being fine and impalpable, capable of scratching corundum. He also burned some of the black residue, and as a product obtained CO_2.

At the meeting, above referred to, of the Academy of Arts and Sciences, Dr. Huntington showed to the members, under a microscope, the slightly yellow transparent grains he had obtained, and called attention to their adamantine luster. Not enough of the clear material was obtained at the time for a chemical test, and, on account of the association of the diamond grains with amorphous carbon, such a test would not have been conclusive without a perfect mechanical separation. One of us (G. F. Kunz) suggested that, if enough of the clear grains could be obtained to polish a diamond, it would conclusively prove that the material was diamond. For this purpose about 200 pounds of the meteoric iron was carefully examined, and specimens which appeared to contain diamonds were dissolved. The method used will be published by one of

* No. 9, p. 258, Dec., 1892.

us (O. W. Huntington) later. After enough material had been separated by Dr. Huntington, on Monday, September 11, 1893, through the courtesy of Messrs. Tiffany & Co., we were enabled to try the desired experiment in their diamond cutting pavilion in the Mining Building of the World's Columbian Exposition, they having prepared a new skaif or wheel, measuring 10½ inches in diameter, which was placed in position, the wheel having been specially planed down and prepared with the radiating scratches so as to be easily charged with diamond powder. A diamond was then soldered in a metal dopp and placed on the clean wheel, which made 2,500 revolutions to the minute. This diamond was tried for more than five minutes by itself without the slightest polish being produced, and no markings other than such as would be produced by the minute shattering of the diamond at extreme edges, due to the friction, as when a diamond is placed on an uncharged wheel. At 9:20 a cleavage, weighing five thirty-seconds of one carat was set with solder in the metal dopp which was placed on the wheel. The diameter of the wheel where the diamond was to be placed was four inches. The wheel was then charged with the residue from the meteorite (the powder mixed as usual with oil). The moment that the diamond was placed on the wheel a hissing noise was apparent, showing to an expert that the material was really cutting the diamond. At 9:23 a flat surface measuring 3^{mm} by 1^{mm} had been ground down and polished. At 9:30 a small crystal with a natural face up was set in the metal dopp, the crystal being a small natural complex twin weighing four thirty-seconds of one carat. It was first tried on a projecting angle. The cutting was very slow for a time, as the natural face of a diamond is always exceedingly hard. The position of the stone was then slightly changed, and a face measuring 2^{mm} by 1^{mm} was ground on the stone and cut. Three minutes later the surface had been cut down somewhat and a decided polish was produced on the triangular face, which was 3^{mm} by 1·25. The fragment used was one of the octahedral faces of a crystal. The face ground down was at the angle of 45 degrees with the octahedral face. The entire time of this experiment was 15 minutes. The two experiments having been made with great care with both of us present, we cannot hesitate to pronounce the material diamond or a substance with the same hardness, color, luster and brilliancy.

In August last, one of us (G. F. Kunz) while examining the hardness of "carborundum," a carbide of silicon, made by Mr. Acheson of Pittsburg,* it was found that it

* See Engineering and Mining Journal.

readily scratched red, blue, white, pink, and yellow corundum in the form of fine gems. It having been suggested that this material would cut and polish a diamond, an experiment was made on a new wheel. After several trials had been made, it was found that carborundum would not scratch or polish the diamond, but on the other hand it was easily scratched by diamond cleavages, and crystal faces. This experiment is only mentioned as it precludes any possibility of the material which has been found in the Cañon Diablo meteorite being any such compound of carbon and silicon, such as the new and interesting abrasive material just mentioned. But it establishes the fact that we have an artificial substance that exceeds all natural substances except the diamond in hardness, i. e. being harder than 9—but still far distant from *10*.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Mass-composition of Water.*—The mass-composition of water has been determined with great care by Dittmar and Henderson, the synthesis being accomplished by the action of hydrogen on copper oxide. A specially devised apparatus was employed for the purpose consisting of the reduction tube, with the necessary purifying and drying train before it and the water receptacle and drying tubes after it. About 115 grams copper oxide was placed in the reduction tube, and this was heated on a magnesia bath in a current of dry air. The next day the tube was exhausted, filled with hydrogen, allowed to assume the temperature of the balance case, again exhausted noting the pressure, and weighed. The apparatus was thus connected together, several liters of hydrogen were passed through it to free it of air, and the reduction tube was heated. The reduction of the copper oxide takes place below redness, the water receptacle being cooled first by ice and then by water. After the reduction is complete, the apparatus is allowed to cool, the hydrogen contained in it is replaced by dry air, and its various parts are disconnected and weighed. The loss of weight of the tube gives the mass of oxygen employed and the increase of weight of the water flask and its drying tubes, the mass of water produced. The values obtained were carefully corrected. The first series of experiments was made to test the apparatus and to acquire familiarity with it. The results of the second series show that as a mean of the experiments 8 grams of oxygen required 1·00879 grams of hydrogen to form water; the result of the seven best experiments being 1·00848 grams. Hence they adopt as the

atomic mass of hydrogen 1·0085 (O = 16); or calling the atomic mass of hydrogen 1, the value 15·866, practically 15·87 as the atomic mass of oxygen. The atomic mass of hydrogen has been found by Stas to be 1·0075, by Cooke and Richards 1·0083, by Noyes 1·0072, by Lord Rayleigh 1·0069 and by Keiser 1·0032.—*Chem. News*, lxvii, 54, 68, 77, 90, 104, 115,126, 139, 151, 164, 1893. G. F. B.

2. *On the Constitution of Hydrogen peroxide and of Ozone.*—In 1886, TRAUBE expressed the opinion that hydrogen peroxide contains its oxygen atoms doubly united, so that this substance is a compound of an oxygen molecule with two hydrogen atoms, $H_2 . O = O$. In support of this view he now brings forward certain significant facts. In the first place, no instance is known of the formation of hydrogen peroxide by the oxidation of water, the author's experiments showing that it is produced synthetically only by the action of molecular oxygen upon hydrogen. Thus it is formed at the kathode of the voltameter, where the evolved hydrogen meets gaseous oxygen. It is produced in processes of slow combustion, as in the case of zinc for example, where the hydrogen set free from the water comes in contact with oxygen gas. It is also generated by the combustion of hydrogen and also by the action of hydrogen palladium upon oxygen. In the second place, hydrogen peroxide exerts an oxidizing action only upon strongly reducing substances, being then rearranged into two hydroxyl groups which unite directly; $Zn + H_2O_2 = Zn(OH)_2$. That these hydroxyl groups do not preexist in the peroxide appears to the author to follow from the complete indifference which this substance shows compared with other oxidizing agents. Thus Schönbein found that it does not react at once upon either phosphorus or phosphorus acid. Welzien states that the titer of a peroxide solution did not change after standing over phosphorus for two months; and Schönbein observed that this substance could even be distilled with ether without decomposition. In alcohol, according to Lustig, the peroxide remains unaltered even in presence of sulphuric acid. In very dilute solution, it liberates iodine from potassium iodide only very slowly and potassium oxalate may be boiled with it without being oxidized. In further proof that hydrogen peroxide does not consist of two hydroxyl groups, the author notes the fact that, were this the case it should be obtained by the electrolysis of barium hydroxide; whereas no trace of it is produced in this process, only ordinary oxygen appearing at the anode. Ozone resembles hydrogen peroxide in many respects. If the constitution of the latter is H–O–O–H, that of the latter must be $\begin{matrix} O-O \\ \backslash O / \end{matrix}$, its three atoms having the same chemical value. But if hydrogen peroxide is $H_2 . O = O$ and ozone $O . O = O$ the doubly united atoms will react differently from the third atom. This latter case appears to be the fact. Thus when ozone acts on sulphurous oxide $SO_2 + O_3 = SO_3 + O_2$. Moreover

ozone and hydrogen peroxide react thus: $O_3+H_2O_2=H_2O+(O_2)_2$; whereas on the single bond theory $O_3+(H_2O_2)_3=(H_2O)_3+(O_2)_3$ would represent the reaction. In these cases only one atom of the oxygen appears to be active. So potassium tetroxide which is ordinarily written K–O–O–O–O–K, actually absorbs oxygen in spite of its large content of this substance, and reduces readily acid solutions of potassium permanganate. None of its oxygen atoms therefore are active, and on treatment with acid it decomposes into hydrogen peroxide and ordinary oxygen, indigo-sulphuric acid, if present in the solution, remaining unaffected. Hence the author writes its formula K . O = O . O = O . K. Such substances as these, which are not active oxidizers, the author thinks should not be called peroxides. He has proposed the name "holoxides" for them, to indicate that the oxygen atoms are doubly united in them and exist as a molecule. While water is a compound of one atom of oxygen, hydrogen holoxide is a compound of one molecule of oxygen with two atoms of hydrogen. He suggests too that oxygen may be trivalent; and in that case would write the constitution of hydrogen holoxide H–O = O–H, of potassium holoxide K–O = O–O = O–K.—*Ber. Berl. Chem. Ges.*, xxvi, 1471, 1476, June, 1893. G. F. B.

3. *On the formation of Ozone at high Temperatures.*—The peculiar odor of the oxygen made from a mixture of potassium chlorate and manganese dioxide has long been recognized, and has generally been confounded with that of chlorine. Schönbein, Chevreul, Poggendorff and others mention chlorine as being evolved in this reaction and Marignac says he obtained 3 mgrms. of silver chloride from the oxygen evolved from 50 grams potassium chlorate. Brunck, reasoning that if the chlorate really gave off chlorine on heating, free alkali would be formed and should exist in the residue either as such or in the form of potassium manganate, has carefully examined this residue and finds it to be completely colorless and perfectly neutral. This fact, taken in connection with the property possessed by the odorous gas, even after washing with strong potash solution, of bluing paper moistened with potassium iodide and starch, led the author to assume that this gas must be ozone. Experiments made with ozonized oxygen showed that ozone may exist not only at the temperature of decomposition of potassium chlorate but even for a short time at a red heat; only 80 per cent of a gas thus prepared being destroyed by passing it through a combustion tube heated to 350°. The quantity passing did not materially diminish when the temperature of the tube reached a dull red. Comparative tests were made between oxygen evolved from the chlorate mixture and oxygen ozonized in a Siemens tube. Both samples set iodine free from neutral potassium iodide, oxidize alcohol to aldehyde, lose their properties when passed over manganese dioxide at ordinary temperatures, and are unchanged by washing with strong potash solution. Though these results establish the identity of the odorous gas with ozone, yet it differs in some particu-

lars from the ordinary forms of this substance. Thus its odor is exactly that of chlorine, its permanence is greater at high temperatures, as is shown by the mode of its production, it does not act upon a mercury surface, and organic bodies such as caoutchouc, are far less readily attacked by it. Moreover, the author observed that while pure potassium chlorate yields perfectly pure oxygen, the slightest trace of any indifferent substance such as potassium chloride or even silica, causes the production of ozone. Hence the purest chlorate of commerce yields an oxygen containing ozone. A mixture of equal parts pure chlorate and manganese dioxide gave on heating a gas containing 0·3 per cent of ozone; and when the dioxide was increased to 25 times the mass of the chlorate, the ozone present amounted to 1·55 per cent. Investigation showed that this action was not produced by all oxides, and that oxides may be divided into three classes: (1) those which are indifferent, such as the oxides of iron, copper and zinc; (2) those which heated by themselves in an atmosphere free from oxygen to the temperature of decomposition, yield ozone, this ozone increasing in amount by heating them in a current of oxygen but is absent when the oxide is heated with chlorate, such as the oxides of silver and mercury and the peroxides of lead and probably barium; and (3) those which give ozone only when heated to the temperature of decomposition in presence of oxygen and which evolve ozone also when heated with potassium chlorate to a temperature considerably below the decomposition-point of this salt, such as cobalt oxide, manganese dioxide and nickel sesquioxide. The author notices the curious fact that the admixture of a small quantity of sodium carbonate with the chlorate and manganese dioxide entirely prevents the production of ozone, the sodium being left in the residue as peroxide.—*Ber. Berl. Chem. Ges.*, xxvi, 1790, July, 1893. G. F. B.

4. *On the Preparation and Properties of pure Nitrogen.*—The preparation of pure nitrogen by various processes has been examined by THRELFALL. He finds that the method depending on the absorption of the oxygen from air by passing it over heated copper is a very objectionable one, since besides the mechanical difficulties of connecting the various tubes to one another at these high temperatures and of preventing their permeability to gases, the chemical difficulties are also serious. The preparation of the pure hydrogen or carbon monoxide for the reduction of the copper oxide is one of the greatest. Removal of the oxygen by passing air over heated phosphorus is also unsatisfactory. And the nitrogen obtained by heating ammonium dichromate, even when this salt was purified with the greatest care, contained nitrous compounds. The method finally adopted was the absorption of the oxygen from air by means of metallic copper and ammonia, the last traces of oxygen being removed by chromous chloride, prepared by Resoura's method and evaporated in an atmosphere of carbon dioxide under diminished pressure. All india-rubber was excluded from the apparatus, the joints were

hermetically sealed, the tops carefully ground and sealed with mercury. The substances employed were themselves carefully purified. The nitrogen thus obtained when examined in a tube furnished with external electrodes, gave a spectrum free from the lines of hydrogen or hydrocarbons. The observation of Thomson and Threlfall in 1887 that nitrogen suffers a diminution of volume on passing the electric discharge through it, the author confirms. But he finds that this effect is not due to a molecular condensation of the gas as originally supposed; but is owing to the production of a compound between the mercury of the gauge and the nitrogen, probably a nitride of mercury analogous to the trimercuramine of Plantamour. This compound appears as a brown film on the glass when the discharge passes through the nitrogen over mercury at about 8^{mm} pressure; nearly the whole of the nitrogen being eventually converted into it. It decomposes at about 200° and re-forms on cooling.—*Phil. Mag.*, V, xxxv, 1, Jan. 1893. G. F. B.

5. *On the Preparation of Carbon under High Pressure.*—A series of experiments has been made by Moissan upon the influence of pressure on the crystallization of carbon at high temperatures. When carbon is dissolved in iron between 1100° and 3000°, either graphite or a mixture of graphite and amorphous carbon separates at the ordinary pressure on cooling. If however, the cooling be effected under a high pressure the phenomena are quite different. To produce this pressure the mass of iron is heated up to 2000° or 3000° and the exterior is rapidly cooled by means of water; this exterior is thereby solidified and the still liquid interior, expanding as it solidifies produces an enormons pressure. Or, charcoal made from sugar is compressed in a soft iron cylinder closed with a screw plug, and the cylinder is plunged into a crucible containing melted iron. The crucible is withdrawn from the fire and placed in water until its exterior is at a dull red, after which it is cooled in the air. By these processes three forms of carbon are obtained, the proportion of each depending on the conditions of the cooling; which are (1) graphite, (2) thin contorted, maroon colored flakes, and (3) diamond. The diamond is obtained as grains of gray-black carbonado, of sp. gr. 3·0 to 3·5 and as transparent fragments, having a waxy luster and marked with striæ. Both these varieties leave a minute ash when burned. Silver also has the power of dissolving carbon. If this metal be heated to boiling in a crucible brasqued with charcoal and then rapidly cooled on the outside by plunging it into water, carbonado of sp. gr. from 2·5 to 3·5 is obtained in small plates.—*C. R.*, cxvi, 218, Feb. 1893. G. F. B.

6. *On the Properties of Diamonds.*—In a subsequent paper Moissan has given the results of an investigation to determine the temperature at which diamonds begin to burn in oxygen, these temperatures being measured by means of a thermoelectric couple. As the temperature is slowly raised, the combustion takes place slowly and without the production of light, the only

evidence of it being the effect produced by the issuing gas on solution of baryta. At about 40° to 50° above this slow combustion temperature, the burning becomes rapid and a distinct flame is visible. The eight different specimens examined gave results as follows: yellowish-brown carbonado burned at 690° with flame; black carbonado at 710°–720° with flame; transparent Brazilian diamond at 760°–770° without a flame; cut diamond from the Cape, at 780°–790°, without a flame; Brazilian bort at 790° without a flame and at 840° with a flame; Cape bort at 790° without a flame and at 840° with a flame; very hard bort at 800° without and at 875° with a flame. The harder the diamond as a rule the higher its point of ignition. Heated in hydrogen to 1200° Cape diamonds do not lose weight, though they may lose their transparency and become lighter in color. At this temperature dry chlorine and dry hydrogen fluoride have no action on them. The vapor of sulphur attacks them only at 1000°; but with carbonado, carbon disulphide is produced at 960°. The vapor of sodium has no action at 600°. Iron at its fusing point attacks the diamond readily and graphite separates on cooling. When heated with alkali carbonates at a high temperature the diamond is rapidly dissolved with evolution of carbon monoxide but no hydrogen. Hence it cannot contain hydrocarbons.—*C. R.*, cxvi, 460, March, 1893. G. F. B.

7. *Oxygen in illuminating Gas.*—While great attention is being paid to the problem of transmitting energy by means of electricity, the problems of accomplishing the same results by means of compressed air and by gas are not being overlooked. In the year 1890 Mr. Edward Tatham, of New South Wales, suggested the addition of considerable quantities of pure oxygen to warm heavy oil gas to produce a higher illuminating power. Dr. L. T. Thorne later in the same year gave the results of some preliminary experiments with such a gas—which were extremely favorable. Preparations are being made at Huddersfield to produce this enriched gas on a large scale. It has been found that the admixture of six per cent oxy-oil gas increases the illuminating power of the corporation gas by the equivalent of five and a half candles. A marked increase is also noticed in the stability of the gas under storage. The increased cost of production due to such enrichment will not exceed a third of a penny per thousand cubic feet.—*Nature*, Oct. 19, 1893. J. T.

8. *Refractive indices of Liquid Nitrogen and Air.*—Professors Liveing and Dewar have determined these constants by the method of MM. Terquem and Trannin. This consists in suspending in the liquid whose index is to be determined, two plates of glass with a thin layer of air between them and measuring the angle of incidence at which the chosen ray suffers total reflexion at the surface of the air. Professor Dewar found "that in a double glass vessel of any form, where the outer and inner vessels are separated by even narrow vacuous spaces, liquid oxygen can be kept for a great length of time open to the air. Such a liquid, filtered

through ordinary filter paper to remove solid carbonic acid, remains quite tranquil and beautifully transparent of a pale blue tint." Liquid oxygen gave $\mu=1{\cdot}226$. Liquid nitrogen at $-190°$ C. and at atmospheric pressure gave for the D line $\mu=1{\cdot}2053$. Liquid air gave for the D ray $\mu=1{\cdot}2062$. When certain proportions of nitrogen had evaporated from the liquid air results were obtained as follows: $\mu=1{\cdot}215$, $\mu=1{\cdot}218$.—*Phil. Mag.*, October, 1893, pp. 328–331. J. T.

9. *Rotation air Pump.*—Sprengel's pump and Geissler's pump are the forms of pumps which are used for obtaining high vacua. F. Schulze Berge has invented a new form which combines the possibility of obtaining a high vacuum with a speed which compares with that of a mechanical air pump. Vacua have been obtained by this pump which are beyond accurate measurement on McLeod's gauge. Several forms of the new pump are given by the author.—*Ann. der Physik und Chemie*, No. 10, 1893, p. 368–376. J. T.

10. *Waves in air.*—A. Raps has employed Jamin's interferential refractor to study the rarefaction and condensation of air while transmitting sound waves. One ray of light is led through air at rest and the other is passed through the air which is in movement. The two rays give interference fringes. These are received through a suitable slit on a revolving cylinder which is covered with photographic paper. The difference in the air paths thus produce vibrating fringes. A spot on a dark fringe and a spot on a bright fringe produce wave-shaped curves which represent the movements of the vibrating air column. In this way the author studies the movement of air in organ pipes and the movement of sound waves in open air. A large number of photographic plates accompany this article.—*Ann. der Physik und Chemie*, No. 10, 1893, pp. 194–220. J. T.

11. *Standards of low Electrical Resistance.*—At the late meeting of the British Association at Nottingham, Principal Jones described a method of determining small resistances which is based upon the Lorenz method of determining this ohm. The method consists in rapidly rotating a copper disc whose center is on and whose rotating axis coincides with the axis of a coil. The same current is led through the coil and the resistance to be measured. The difference of potential between the center and circumference of the rotating disc is made to counterbalance that at the ends of the resistance to be measured. A series of experiments on a resistance of $\frac{1}{2000}$ of an ohm was given and it showed that the variation from the mean of the extreme values was 1 in 12,000. J. T.

12. *Equipotential and magnetic force-lines.*—E. von Lommel returns to a discussion of his explanation of the Hall effect. He gives several plates of the distribution of magnetic filings upon plates of various forms through which powerful currents are led and compares these figures with representations of equipotential lines and magnetic lines on similar formed plates given by Quincke

(Pogg. Ann. xcviii, p. 382, 1856). He concludes that the Hall effect is due to the shifting of the equipotential lines or surfaces due to the electric current in a strong magnetic field.—*Ann. der Physik und Chemie*, No. 10, 1893, p. 316. J. T.

13. *Hand- und Hilfsbuch zur Ausführung Physiko-chemischer Messungen*, von W. Ostwald, 1893, Leipzig (W. Engelmann.)—In this handy little volume of three hundred pages Ostwald has condensed the results of his extended and very exceptional experience in the practical details of the conduction of research in physical chemistry. The chapters treating glass blowing, weighing and the determination of solubilities and of molecular weights contain many valuable suggestions about these ordinary manipulations of the laboratory. Those on the determinations of temperatures, pressures, densities, surface tensions, heat quantities and critical data, together with those on optical and electrical measurements have very especial interest for the physical chemist, and they would be of great service in purely physical work. The descriptions and explanations are all admirably clear, the book is practically arranged and well printed, and it is accompanied by various separately printed tables which materially enhance its practical value. J. E. T.

II. Geology and Mineralogy.

1. *The origin of Crystalline Schists.*—In an address before the Geological Section of the British Association, Mr. J. J. H. Teall, combatted strongly the common idea that crystalline schists belong exclusively to the earliest periods of the earth's history. He expressed himself as follows:

"The crystalline schists certainly do not form a natural group. Some are undoubtedly plutonic igneous rocks showing original fluxion; others are igneous rocks which have been deformed by earth-stresses subsequent to consolidation; others, again, are sedimentary rocks metamorphosed by dynamic and thermal agencies, and more or less injected with 'molten mineral matter'; and lastly, some cannot be classified with certainty under any of these heads. So much being granted, it is obvious that we must deal with this petrographical complex by separating from it those rocks about the origin of which there can be no reasonable doubt. Until this separation has been effected, it is quite impossible to discuss with profit the question as to whether any portions of the primitive crust remain. In order to carry out this work it is necessary to establish some criterion by which the rocks of igneous may be separated from those of sedimentary origin. Such a criterion may, I think, be found, at any rate in many cases, by combining chemical with field evidence. If associated rocks possess the composition of grits, sandstones, shales, and limestones, and contain also traces of stratification, it seems perfectly justifiable to conclude that they must have been originally formed by processes of denudation and deposition. That we have such rocks in

the Alps and in the central Highlands of Scotland, to mention only two localities, will be admitted by all who are familiar with those regions. Again, if the associated rocks possess the composition of igneous products, it seems equally reasonable to conclude that they are of igneous origin. Such a series we find in the northwest of Scotland, in the Malvern Hills, and at the Lizard. In applying the test of chemical composition, it is very necessary to remember that it must be based not on a comparison of individual specimens, but of groups of specimens. A granite and an arkose, a granitic gneiss and a gneiss formed by the metamorphosis of a grit, may agree in chemical and even in mineralogical composition. The chemical test would therefore utterly fail if employed for the purpose of discriminating between these rocks. But when we introduce the principle of paragenesis it enables us in many cases to distinguish between them. The granitic gneiss will be associated with rocks having the composition of diorites, gabbros, and peridotites; the sedimentary gneiss with rocks answering to sandstones, shales, and limestones. Apply this test to the gneisses of Scotland, and I believe it will be found in many cases to furnish a solution of the problem."

" . . . The origin of gneisses and schists, in my opinion, is to be sought for in a combination of the thermal and dynamic agencies which may be reasonably supposed to operate in the deeper zones of the earth's crust. If this view be correct, it is not improbable that we may have crystalline schists and gneisses of post-Silurian age in the northwest of Europe formed during the Caledonian folding, others in central Europe of post-Devonian age due to the Hercynian folding, and yet others in southern Europe of post-Cretaceous age produced in connection with the Alpine folding. But if the existence of such schists should ultimately be established, it will still probably remain true that rocks of this character are in most cases of pre-Cambrian age. May not this be due to the fact, suggested by a consideration of the biological evidence, that the time covered by our fossiliferous records is but a small fraction of that during which the present physical conditions have remained practically constant?"—*Nat. Science*, Oct. 1893.

2. *Ore Deposits of the United States;* by Prof. J. F. Kemp. 8vo, pp. 302. New York, 1893 (The Scientific Pub. Co.).—The author after several preliminary chapters treating on classification, the mode and occurrence of ores as deposits and in mineral veins, then proceeds to the main body of the work. This takes up each of the metals in turn and describes concisely one occurrence typical of the method of classification. The similar occurrences in other localities are mentioned and a full list of the literature is given. Thus all the various methods of occurrence of each metal and its ores are shown. The volume is copiously illustrated with cuts and diagrams. The author has collected within brief compass a vast amount of useful information while the very full bibliography greatly enhances its value. The appear-

ance of this work is opportune and it will be of great service to students in metallurgy, miners and in general to the public interested in mines and mining. No book of similar scope has appeared in this country since that of J. D. Whitney in 1855.

L. V. P.

3. *Sach- und Orts-Verzeichniss zu den Mineralogischen und Geologischen Arbeiten von Gerhard vom Rath.* Im Auftrage der Frau vom Rath bearbeitet von W. Bruhns und K. Busz. 197 pp. Leipzig, 1893 (W. Engelmann).—The scientific career of Professor G. vom Rath was remarkable alike for the amount of mineralogical work which he accomplished as for the minute care and accuracy displayed through it all. His skill in solving the most intricate problems in crystallography and in presenting the results to the eye will always be a matter of admiration to those who study his papers. To all concerned with mineralogical literature the present complete index to his many papers will be most useful, forming as they do a very important part in the history of the science.

4. *Mineralogisches Lexicon für das Kaiserthum Oesterreich von V. von Zepharovich.* III Band, enthaltend die Nachträge aus den Jahren 1874–1891 und die General Register. Nach des Autors hinterlassenem Manuscripte bearbeitet von F. Becke. 478 pp. Vienna, 1893 (F. Tempsky).—This volume is published by the Vienna Academy at the cost of the Zepharovich fund. It forms the conclusion to the author's well known work upon the Mineralogy of Austria and is edited from the manuscript left by him. An alphabetical list of localities referring to the three volumes occupies the last two hundred pages.

5. *Handbuch der Mineralogie von* Dr. C. Hintze. Siebente Lieferung. pp. 961–1120. Leipzig (Veit and Co.).—The seventh part of this exhaustive work, recently issued, is devoted to the orthorhombic and monoclinic members of the Pyroxene group.

6. *On the meteorite from Hamblen Co., Tennessee;* by L. G. Eakins (communicated).—In a paper upon the Hamblen Co. meteorite in this Journal for October, 1893, there occur some errors in figuring the formulas of the siliceous portions, to which Prof. S. L. Penfield has very kindly called my attention. This part of the paper was hastily written several months after the analytical work was done, and to this haste, caused by pressure of entirely different matters, these errors are due. As Prof. Penfield suggests, the soluble portion of the silicates, giving the ratios: $RO : Al_2O_3 : SiO_2 = \cdot506 : \cdot222 : \cdot760$, can, by assuming the FeO and MgO to exist as olivine, be divided, approximately into olivine and a calcium-aluminum silicate like anorthite, both of which are soluble in hydrochloric acid. The insoluble portion reduces to, $RO : Al_2O_3 : SiO_2 = \cdot670 : \cdot146 : \cdot844$, which probably represents a mixture of pyroxene and enstatite; one or both being aluminous.

III. Miscellaneous Scientific Intelligence.

1. *Letters of Asa Gray*, edited by Jane Loring Gray. 2 vols., 8vo. Boston and New York. 1893. (Houghton, Mifflin and Company).—This collection of letters illustrates Dr. Gray's scientific career, and much of his home-life, from his first acquaintance with Dr. Torrey, about 1831, down to November 27, 1887, the last active day of his life. In respect to home-life, and among his friends, they reveal the genial, kind, sympathetic, christian gentleman, and in respect to his favorite science they show a constantly widening view, from the time when he began to notice the more interesting plants of Oneida county, onward through his study of the flora of North America and his contributions to general botany, through his broader studies of the relations of botany to other sciences, until, his interest undiminished, and his judgment clear, he suddenly rested from his labors. Many of the letters written from 1860 for the next score of years are to Mr. Darwin, or relate in some way to the investigations which Mr. Darwin was making, or the theories he was advancing, and would furnish good material for "The evolution of Darwinism," were such a chapter to be written. Other letters contain a history of the "Flora of North America," almost from its beginning in 1838, through the period when new plants were pouring in from the Rocky Mountain region and the Pacific States faster than they could be classified, down to the days, when having completed the "Gamopetaleæ" of the "Synoptical Flora," the aged botanist was revising the earlier orders, although with the confession that "I begin to doubt if I shall hold out to accomplish much more." The last letter of all contains his final dictum on nomenclature and the warning that "this business of determining rightful names is not so simple and mechanical as to younger botanists it seems to be, but is very full of pitfalls." The editing of these Letters has been done most carefully and judiciously; and those who knew the kind and many-sided naturalist will only wish that more of them had been printed. D. C. E.

2. *National Academy of Sciences.*—The following is a list of papers presented at the meeting of the National Academy, held in Albany, Nov. 7–9:

Samuel H. Scudder: American Palæozoic cockroaches.

Seth C. Chandler: Additional researches on the motion of the Earth's pole.

C. A. White: Biographical memoir of A. H. Worthen.

C. B. Comstock: Biographical memoir of W. P. Trowbridge.

James Hall: The geological map of the State of New York. The Palæontology of the State of New York: the present condition of the work.

George L. Goodale: Certain Histological relations between the subalpine Plants of the White Hills and of the Labrador coast.

Charles S. Hastings: On a new form of telescopic objective, as applied to the twelve-inch equatorial of the Dudley Observatory.

Charles E. Beecher: On the structure and development of Trilobites.

Asaph Hall: Double stars

Charles L. Doolittle: Latitude determinations at the Sayre Observatory.

Joseph A. Lintner: Insect voices.

CHARLES H. PECK: Edible and poisonous Fungi.
EDWARD S. MORSE: A new process of printing in color.
J. MCKEEN CATTELL and CHARLES S. DOLLEY: On Reaction—times and the velocity of the nervous impulse.

3. *Annalen der Physik und Chemie*, published in Leipzig since 1790 by Johann Ambrosius Barth (now Arthur Meiner).—This long honored periodical has now completed more than a century. It was begun by Gren in 1790, continued till 1824 by Gilbert, again till 1877 by Poggendorff and is now edited by Prof. G. Wiedemann. The first number of the 50th volume is devoted to the present editor, a biographical sketch of whom is given by Prof. Helmholtz; an excellent portrait forms the frontispiece.

Die Photographie: oder die Anfestigung von bildlichen Darstellungen auf künstlichen Wege. Lehr- u. Handbuch von praktischen und theoretischer Seite; bearbeitet und herausgegeben von Julius Krüger: zweite Auflage, gänzlich neu bearbeitet von Ph. C. J. Husnik, 494, 12mo. Wien, Pest, Leipzig (A. Hartleben).

OBITUARY.

ARCANGELO SCACCHI, the veteran mineralogist of Naples, whose long continued labors on the mineralogy and geology of Monte Somma and Vesuvius, have given such rich results to science, died on the 11th of October.

HERMANN AUGUST HAGEN, the well known entomologist, and since 1870, Professor of Entomology at Harvard University, died on the 10th of November. He was born at Königsberg, Prussia, in 1817 and his scientific work for many years was done there. In 1867, at the invitation of Professor Agassiz, he came to this country to take a position in connection with the Cambridge Museum of Comparative Zoölogy. Among his many important contributions to science, the most extended is his Bibliotheca Entomologica, published in 1862.

DR. GEORGE W. COAKLEY, emeritus professor of mathematics and astronomy in the University of the City of New York, died at his home in Brooklyn on the 2d of August, in the seventy-ninth year of his age. He came to this country from the West Indies during his boyhood, and was graduated with honor from Rutgers College in New Jersey. After some years of work as a teacher of mathematics, first in New York State and afterward in Maryland, he was called to New York City about 1860, to assume the chair made vacant by the withdrawal of Professor Elias Loomis, who had just changed his residence from New York to New Haven. Professor Coakley continued his work here for thirty years. As a teacher he was indefatigable, patient, and skillful. In personal disposition he was too modest and retiring to secure for himself all the recognition that was due him. During the latter years of his life he published a number of papers on astronomical subjects, and his last work was a text-book on Calculus, which has not yet been published. During a protracted illness his interest in astronomical progress never flagged, and his clearest and best writing was done after disease had unfitted him for active work.

W. LEC. S.

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